EXHIBIT

G

AFFIDAVIT OF STEPHEN E. PETTY, P.E., C.I.H., C.S.P.

Before me, the undersigned authority, on this day personally appeared STEPHEN E. PETTY ("Affiant") who, being by me first duly sworn, deposes and says:

1. I am an adult in sound mind and body and have personal knowledge of the fact averred herein.

2. Since April 14, 1996, I have owned and operated EES Group, Inc., a consultancy corporation specializing in health and safety and forensics.

3. I hold relevant industry certifications including board certifications as a C.I.H. (Certified Industrial Hygienist), a C.S.P. (Certified Safety Professional), and a P.E. (Professional Engineer) in six states (Florida, Kentucky, Ohio, Pennsylvania, Texas, and West Virginia). My curriculum is attached hereto as **Exhibit i**.

4. I have served as an expert in personal protective equipment and related disciplines in approximately 400 legal cases. I am certified in and have provided testimony as an expert in these areas. My list of representative cases is attached hereto as **Exhibit ii**.

5. For example, I am currently serving as an expert in the Monsanto Roundup and 3M PFAS litigation. Recently I testified in four trials for the DuPont C8 litigation.

6. I taught Environmental and Earth Sciences as an adjunct professor at Franklin University.

7. I hold nine U.S. patents relating to heating, ventilation and air conditioning (HVAC) systems.

8. I am a current member in good standing of the following relevant associations: American Industrial Hygiene Association (AIHA), American Board of Industrial Hygiene (ABIH), American Conference of Governmental Industrial Hygienists (ACGIH), American Institute of Chemical Engineers (AIChE), American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE); Member ASHRAE 40 Std. and TC 2.3, and Sigma Xi.

9. I am an expert in the field of Industrial Hygiene, which is the science and art devoted to the anticipation, recognition, evaluation, and control of those environmental factors or stressors — including viruses — arising in or from the workplace, which may cause sickness, impaired health and well-being, or significant discomfort among workers or among the citizens of the community.

10. Industrial Hygiene is fundamentally concerned with the proper methods of mitigating airborne/dermal hazards and pathogens, as well as with the design and use of engineering controls, administrative controls, and personal protective equipment, among other things.

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11. Medical doctors, virologists, immunologists, and many public health professionals are not qualified experts in these areas by virtue of those aforementioned credentials.

12. On May 7, 2021, the Centers for Disease Control (CDC) updated its guidance, providing that the primary mechanism for transmission of Covid-19 is through airborne aerosols, and not, as previously stated, by touching contaminated surfaces or through large respiratory droplets, as also stated during previous periods of the pandemic.

13. Airborne viral aerosols can consist of a single viral particle or multiple viral particles clumped together, and usually smaller than 5 μ (microns) in size. By comparison, droplets are >5 μ to >10 μ in size.

14. The area of a micron by a micron is approximately 1/4,000th of the area of the cross-section of a human hair and 1/88th the diameter of a human hair. Covid particles are 1/10 of a micron or ~1/40,000th of the area of a cross section of a human hair and ~1/880th the diameter of a human hair.

15. A recent University of Florida study capturing air samples within an enclosed automobile cabin occupied by a Covid-positive individual showed that the only culturable Covid-19 virus samples obtained were between 0.25μ to 0.5μ in size. Particles smaller than 5μ are considered very small and/or very fine or aerosols.

16. Very small particles do not fall by gravity in the same rate that larger particles do and can stay suspended in still air for a long time, even days to weeks.

17. Because they stay suspended in concentration in indoor air, very small particles can potentially accumulate and become more concentrated over time indoors if the ventilation is poor.

18. Very small airborne aerosols pose a particularly great risk of exposure and infection because, since they are so small, they easily reach deep into the lung. This explains in part why Covid-19 is so easily spread, and why so little Covid-19 is required for infection.

19. Exposure to airborne aerosols is a function of two primary parameters: concentration and time. Less is better regarding both parameters.

20. For many reasons, personal protective equipment (PPE) is the <u>least</u> desirable way to protect people from very small airborne aerosols. Moreover, masks are not PPE since they cannot be sealed and do not meet the provisions of the Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard (RPS), namely 29 CFR 1910.134.

21. Regarding PPE, facial coverings do not effectively protect individuals from exposure to very small airborne aerosols. A device referred to as a respirator is required to provide such protection.

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22. The AIHA, in their September 9, 2020 Guidance Document for COVID-19 (**Exhibit iii**) noted that the acceptable relative risk reduction methods must be ≥90%; masks were shown to be only 10% and 5% (see Exhibit iii - Figure 2) and far below the required 90% level.

23. Similarly, Shah et al, 2021 (**Exhibit iv**), using ideally sealed masks and particles 1 micron in size, reported efficiencies for the more commonly used cloth masks and surgical masks of 10% and 12% respectively. No mask can be perfectly sealed, thus "real world" effectiveness would be even lower.

24. Industrial hygienists refer to a "Hierarchy of Controls" that are typically implemented to minimize exposures, including exposures to very small airborne aerosols like Covid-19.

25. Regarding practical or "engineering" controls, industrial hygienists focus on practices that dilute, destroy, or contain airborne hazards (or hazards in general).

26. PPE — especially facial coverings — do not dilute, destroy, or contain airborne hazards. Therefore, facial coverings are not contained in the Industrial Hygiene (IH) Hierarchy of Controls. Even respirators (part of the PPE Category and not masks) are in the last priority on the Hierarchy of Controls.

27. Facial coverings are not comparable to respirators. Leakage occurs around the edges of ordinary facial coverings. Thus, ordinary facial coverings <u>do not</u> provide a reliable level of protection against inhalation of very small airborne particles and are not considered respiratory protection.

28. For example, during the seasonal forest fires in the summer of 2020, the CDC issued public guidance warning that facial coverings provide no protection against smoke inhalation. That is because facial coverings do not provide a reliable level of protection against the small particles of ash contained in smoke. Ash particles are substantially larger than Covid-19 aerosolized particles.

29. I have reviewed the Mayfield City School District (MCSD) "Protective Facial Covering Policy During Pandemic/Endemic Events" as set forth in the Policy Manual of the MCSD Board of Education.

30. Ordinary facial coverings like the ones required by the MCSD facial covering policy do not meet any of the several key OSHA Respiratory Protection Standards for respirators.

31. Because of the gaps around the edges of facial coverings required by MCSD's policy, they do not filter out Covid-19 aerosols. The policy stating masks will be worn without gaps defies known science that masks worn today cannot be sealed and always have gaps.

32. The effectiveness of a cloth facial covering falls to zero when there is a 3% or more open area in the edges around the sides of the facial covering.

33. Most over-the-counter disposable facial coverings have edge gaps of 10% or more. When adult-sized facial coverings are used by children, edge gaps will usually greatly exceed 10%.

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32. Even short breaks (e.g. to eat) expose individuals to Covid-19 aerosols in indoor spaces.

33. Ordinary cloth facial coverings like the ones required by the MCSD mask requirement do not provide any filtering benefit relative to particles smaller than 5μ if not sealed.

34. Substantial mitigation of Covid-19 particles could be immediately achieved by:

a. opening windows and using fans to draw outdoor air into indoor spaces (diluting the concentration of aerosols),

b. setting fresh air dampers to maximum opening on HVAC systems,

c. overriding HVAC energy controls,

d. increasing the number of times indoor air is recycled,

e. installing needlepoint ionization technology to HVAC intake fans, and

f. installing inexpensive ultraviolet germicide devices into HVAC systems.

35. All of the above-referenced techniques are more effective and meet standard industrial hygiene hierarchy of controls (practices) for controlling exposures in place for nearly 100 years. The use of cloth facial coverings do not fit within these basic hierarchy of controls since masks are not PPE and cannot be sealed. There are no OSHA standards for facial coverings (masks) as respiratory protection.

36. Extended use of respiratory PPE is not indicated without medical supervision.

37. As explained in an article titled "Is a Mask That Covers the Mouth and Nose Free from Undesirable Side Effects in Everyday Use and Free of Potential Hazards?" that was published on April 20, 2021, in the *International Journal of Environmental Research and Public Health* and that is attached to this Affidavit as **Exhibit v**, the following negative effects from wearing masks was reported in the literature:

Increased risk of adverse effects when using masks:

Internal diseases COPD Sleep Apnea Syndrome advanced renal Failure Obesity Cardiopulmonary Dysfunction Asthma	**Psychiatric Illness** Claustrophobia Panic Disorder Personality Disorders Dementia Schizophrenia helpless Patients fixed and sedated Patients	**Neurological Diseases** Migraines and Headache Sufferers Patients with intracranial Masses Epilepsy
Pediatric Diseases Asthma Respiratory diseases Cardiopulmonary Diseases Neuromuscular Diseases Epilepsy	**ENT Diseases** Vocal Cord Disorders Rhinitis and obstructive Diseases **Dermatological Diseases** Acne Atopic	**Occupational Health Restrictions** moderate / heavy physical Work **Gynecological restrictions** Pregnant Women

Figure 5. Diseases/predispositions with significant risks, according to the literature found, when using masks. Indications for weighing up medical mask exemption certificates.

Example statements made in the paper include the following: "The overall possible resulting measurable drop in oxygen saturation (O2) of the blood on the one hand and the increase in carbon dioxide (CO2) on the other contribute to an increased noradrenergic stress response, with heart rate increase and respiratory rate increase, in some cases also to a significant blood pressure increase." Exhibit v, p. 25. In fact, "Neither higher level institutions such as the WHO or the European Centre for Disease Prevention and Control (ECDC) nor national ones, such as the Centers for Disease Control and Prevention, GA, USA (CDC) or the German RKI, substantiate with sound scientific data a positive effect of masks in the public (in terms of a reduced rate of spread of COVID-19 in the population)." Exhibit v, p. 24, for these reasons, students who are required to wear masks pursuant to a mandate suffer immediate and irreparable injury, loss, or damage.

38. In summary:

a. PPE is the least desirable way to protect people from very small airborne aerosols.

b. Facial coverings as required by the MCSD policy are not recognized as PPE since they cannot be sealed and are not covered by the OSHA RPS.

c. If PPE were to be used for protection, respirators, not facial coverings as required by the MCSD policy are needed to provide any effective protection from very small airborne aerosols.

d. Very small aerosol particles are more likely to be a greater cause of disease than respiratory droplets because they can evade PPE and reach deep into the lungs, whereas respiratory droplets have to work against gravity in order to travel up a person's nose into the sinus.

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e. Much better alternatives to controlling exposure are available (i.e., engineering controls of dilution – ventilation with increased fresh air and destruction), and should be used to minimize exposures as opposed to masks.

f. Individuals who are required to wear masks pursuant to a mandate suffer immediate and irreparable injury, loss, and damage due to the overall possible resulting measurable drop in oxygen saturation of the blood on one hand and the increase in carbon dioxide on the other, which contributes to an increased noradrenergic stress response, with heart rate increase and respiratory rate increase and, in some cases, a significant blood pressure increase.

Stephen Petty

Stephen Petty, P.E., C.I.H., C.S.P.

STATE OF OHIO

COUNTY OF FRANKLIN

Sworn to and subscribed before me this 1st day of September, 2021, by Stephen Petty, ( ) who is personally known to me or ( ) who produced FL: drivers License as identification.

Lori A. Jones

NOTARY PUBLIC, State of Ohio

Commission No.

My commission expires: 2-3-2026

NOTARY PUBLIC STATE OF OHIO

LORI A JONES
Notary Public
State of Ohio
My Comm. Expires
February 3, 2026

Mr. Stephen E. Petty, P.E., C.I.H., C.S.P.
President

Company

EES Group, Inc.
(d/b/a - Engineering & Expert Services, Inc.)
1701 E. Atlantic Blvd., Suite 5
Pompano Beach, FL 33060

Education

B.S., Chemical Engineering, University of Washington

M.S., Chemical Engineering, University of Washington

M.B.A., University of Dayton

Experience

General

Mr. Petty is President of EES Group, Inc. (Engineering & Expert Services, Inc.). He started EES Group, Inc. in 1996, ultimately having offices in Ohio (Columbus and Cleveland) and in Florida (Pompano Beach). In 2015, he sold the Ohio portion of EES Group, Inc. while retaining Florida operations. Prior to starting EES Group, Inc. in 1996, Mr. Petty was the Manager of Residential and Commercial Technology at Columbia Energy and a Senior Research Engineer at Battelle. He has 37 years of forensic engineering, environmental health and safety, and energy experience. Since 2002, he has completed or supervised over 7,000 engineering forensic and health and safety projects for nearly 100 clients. This culminated in the writing of a Forensic Engineering textbook targeted at assessing claims for the insurance industry (*Forensic Engineering: Damage Assessments for Residential and Commercial Structures*, January 3, 2013, CRC Press publication; 2nd Edition to issue in 2022).

Mr. Petty's health and safety experience has focused on projects for the legal community (expert witness), the insurance industry, institutions, and the private sector. His expertise covers the area of Professional Engineering (PE's in six states), Industrial Hygiene (registered Certified Industrial Hygienist - CIH) and safety (registered Certified Safety Professional - CSP). As a CIH, he investigates the causes/solutions of an individual's sickness, impaired health, and discomfort at work and in the home. As a CSP, he investigates situations primarily arising out of possible Occupational Safety and Health Administration (OSHA) violations associated with workplace injuries. In other cases, this extends to customers injured at facilities where they are working or shopping. Finally, he is a certified Asbestos Evaluation Specialist in Ohio.

Mr. Petty has been involved in ~400 expert witness cases to date, with a primary focus on exposure to organic chemicals, inorganic chemicals, pesticides, PFOA, PFAS, mold, bacteria (Legionella), heat and bio-toxins; OSHA workplace compliance (chemical exposures, amputations, and slips, trips and falls, and building envelope systems). He has also supported/testified on building envelope, water cause and origin, structural, and roof damage claims. His company assembled a nine-member team of experts that

won the expert witness contract for the Ohio School Facilities Commission (OSFC) from 2004-2008.

Mr. Petty has extensive expertise on heating, ventilation and air conditioning (HVAC) systems and holds nine (9) U.S. patents primarily related to HVAC systems.

His safety and environmental experience also includes completion of many complex projects in Risk Assessment (BUSTR, EPA and VAP), Industrial Hygiene, Process Safety Management (PSM), Risk Management Plans (Health and Safety Audits), Environmental Assessments (EA) and Environmental Impact Statements (EIS), and air and water permits (PTI, PTO, NPDES, etc.) for numerous clients across the United States.

Finally, he has served in a leadership role in technology evaluations, business plans, and product development activities for dozens of products and ventures. He has been the invited dinner/lunch speaker to ASHRAE/AIHA and legal association functions.

Health and Safety Experience

- Mr. Petty has been utilized as an expert witness in ~400 cases primarily related to human exposure(s) and safety (OSHA). In the exposure area, he has worked/ testified on cases of exposure to acid gases, benzene, isocyanates, formaldehyde, gasoline, paint products, other organic chemicals, PFOA/PFAS silica, pesticides, Legionella and other bacteria and molds. In the safety area, he has worked/testified in worker exposure to chemicals, falls, and amputation cases and the standard of care required to protect workers and customers. He is recognized for his ability to reduce complex sets of information regarding exposure and compliance with regulatory standards into simple but accurate reports and presentations. Areas of practice include:
  - Occupational Safety and Health Administration Regulations:
    - OSHA Health and Safety Regulations for Workers 29 CFR 1910 General Industry and 29 CFR 1926 Construction Industry
    - OSHA Process Safety Management of Highly Hazardous Chemicals - 29 CFR 1910.119
    - Personal Protective Equipment - PPE - 29 CFR 1910.132
    - Respiratory Protection Standard - 29 CFR 1910.134 and preceding/current ANSI Z88 Standards.
    - 29 CFR 1910.1000 - OSHA PEL and Controls Standard
    - 29 CFR 1910.1028 - Benzene Standard
    - Hazard Communication Standard - HAZCOM - 29 CFR 1910.1200 and preceding/current ANSI Z129.1 (Precautionary Labeling), ANSI Z400.1 (MSDS Preparation) and LAPI Industry Standards (7 Editions from 1945 forward).
  - Mine Safety Health Administration (MSHA) EH&S Regulations - 30 CFR Parts 1 to 199

- United State Environmental Protection Agency - USEPA - 40 CFR (Including pesticides, hazardous wastes, permitting, remediation, and Process Safety Management).
- DOT Transportation Regulations and Spill Response - Hazardous Waste Operations and Emergency Response (HAZWOPER) - 46 CFR.

Mr. Petty is also trained in Hazardous Waste Operations and Emergency Response (HAZWOPER) (40-hr.) and has served as a trainer for the 40-hr. course.

➢ Mr. Petty is a recognized expert in Risk Assessment (RA) having been one of 14 to take the first Risk Assessment courses offered by the Ohio State University & University of Cincinnati Schools of Public Health in 1997. In addition to having completed a dozen risk assessments, he was selected by the State of Ohio Bureau of Storage Tank Regulators (BUSTR) to help write their 1999 UST RA regulations. He was selected to train BUSTR staff RA (5-week course) and to help write the on-line RA webpage, proof the equations, and to help with the on-line help handbook.

➢ He has completed dozens of indoor air sampling projects for residential, commercial, and industrial clients. Clients include Grange Insurance Company, Northwest Local School District, Children's Hospital, Berger Hospital, Citgo, Salem University, and Nestle.

➢ He has completed dozens of mold field evaluation projects. In this area, he attended a one-week ACGIH mold course in late 2002. He also received his residential mold inspector credentials from the IESO in 2003.

➢ Examples of specific projects completed are:

- Conducted worker illness IAQ program where Iraqi documents were being scanned. Sampled for anthrax, bio-toxins, mold, bacteria, VOCs, CO and CO_2, temperature and humidity to help determine cause of worker complaints.
- Sampled surface and materials for anthrax and bio-toxins at two commercial facilities.
- Selected and completed analysis to determine cause of illness to players in their locker room at Nationwide Arena for the Columbus Blue Jackets professional hockey team.
- Served as an expert to the OSFC on building HVAC and human comfort issues in school buildings.
- Developed implementation templates for several Process Safety Management (PSM) and Risk Management Program (RMP) clients (e.g. Nestle facilities).
- Prepared public meeting presentation materials for AEP RMPs at their Conesville and Tanners Creek power plants. Focus was to match public legal requirements with needs of the client, and development and presentation of worst case and alternative case release scenarios under Part 68 of 40 CFR.

- Completed PSM programs for two Southwest Research Institute (SwRI) facilities and two Nestle facilities. Focus was on completing process hazards analyses (PrHAs) and on setting up ongoing PSM programs. For Nestle, set up file-based system, wrote plans for all 14 major elements, and provided detailed checklists and guidance on sections such as training, mechanical integrity, etc.
- Completed multiple ventilation projects for American Electric Power Plant facilities to determine best locations (performance vs. cost) for hazardous gas monitors in power plants and whether or not ductwork was contaminated with mold.
- Completed series of EH&S projects for Dublin schools (e.g. air quality audits and noise analyses). Completed air clearance testing and reporting and held public meetings for the vandalism clean-up efforts of Grizzell Middle School.
- Conducted industrial hygiene audits and testing for numerous public and private clients. Focused on HVAC systems, sampling (CO, CO_2, relative humidity, molds, dust, bacteria, formaldehyde, VOCs, and isocyanates) and remediation/abatement.
- Completed Failure Modes & Effects Analyses (FMEA) for DOD BZ Nerve Agent Plant design. Plant was later built, operated, and decommissioned in Pine Bluff, AR without incident.

➢ Developed IAQ solutions based on ASHRAE Standards and new technologies (e.g. desiccants).

➢ Developed and taught OSHA HAZWOPPER courses (40-hr, 24-hr and 8-hr).

➢ Voting member ASHRAE TC 8.3; corresponding member ASHRAE TC 3.5 (Desiccants).

➢ Adjunct Professor at Franklin University. Instructor of Environmental and Earth Sciences courses.

Engineering Experience

➢ President and Owner of EES Group, Inc. (EES) since 1996. Developed EES into one of the leading forensic companies in the state of Florida and Ohio.

➢ Author of *Forensic Engineering: Damage Assessments for Residential and Commercial Structures*, January 3, 2013, a CRC Press publication (2nd Edition to issue in early 2022). The book provides guidance on engineering claims assessments for the insurance industry.

➢ Developed forensics libraries and technical bulletins on how to assess insurance claims and fraud associated with claims. Lead author of refereed journal article reviewing hail damage from ~750 individual assessments.

➢ Completed or supervised over 7,000 forensics inspection projects for ~100 insurance companies and other private sector clients since 2002. Projects were associated with structural failures in residential and commercial buildings,

structural damage and failures caused by vehicles striking buildings, water causation and origin analysis, causes of plumbing failures, HVAC failures and damage, roof system failures and structural damage, mold cause, origin and removal, lead cause and removal, hail damage, and lightning claims. Also completed or supervised over 200 insurance appraisals (negotiated settlements) for the industry. Was selected and completed role as an umpire for a 36-building one million dollar hail claim dispute. Testified in trial on roofing claim disputes. Specifically requested for difficult projects and for projects in the state of Texas.

- Led company in efforts to bid and win roofing and environmental contracts with the Ohio School Facilities Commission (OSFC).
- Managed the turnkey design, permitting, and building of a fuel farm facility ($750K) for The Ohio State University (OSU) Airport (2000). Project entailed the layout, design, and installation of six aboveground storage tanks (ASTs), 12,000 gallons each, and the removal and closure of four existing USTs. Fuels included Jet-A and Av-Gas. Project roles included site plans/layouts, preparation of subcontractor specifications, construction oversight, concrete foundation and subsurface design, permitting (PTI and PTO), start-up troubleshooting, and commissioning activities.
- Was lead researcher on two teams of nationally recognized residential and commercial heat pump development programs: i) Battelle (Double-Effect Absorption Heat Pump) and ii) Columbia Gas System (Dual Cycle Heat Pump). Both projects met goals for performance (efficiency and capacity). Research resulted in receipt of six U.S. Patents.
- Co-designed parking lot and storm-water collection system for major trucking firm on 40-acre site in Cleveland. Project began as a site assessment and concluded with facility design.
- Process engineer for 200 million gallons-per-day wastewater treatment plant for a Weyerhaeuser paper mill.
- Evaluated incineration technology and cost/benefit for an incinerator that burned organophosphate and chlorinated thio-ether wastes. Developed source term for present and future emissions under varying load rates.
- Prepared a carbon treatment designs for removing organophosphates and chlorinated thio-ether, and nerve agents from wastewater.
- Designed/permitted first of three mobile wastewater treatment facilities in the State of Ohio.
- Developed a process to eliminate HF/tar hazardous waste generation from an electronics manufacturing process.
- Developed processes to reduce contamination of water from oil spills, including biodegradation and controlled combustion.
- Conducted bench-scale analysis of reverse osmosis, ultrafiltration, wet air oxidation, and solvent extraction treatment processes.

Environmental Experience

- Provided 8-hr. Tier 1 & Tier 2 training to State of Ohio BUSTR site coordinators (May 23, 2000).
- Provided approximately 40 hours of Risk Assessment Training (five 8-hr. training sessions) to BUSTR coordinators (May 1999).
- Member of BUSTR's new rules advisory committee (1999).
- Completed over a dozen BUSTR Tier 2 and Tier 3 Risk Assessments (RA) for clients such as CITGO, AEP, Anderson Concrete, and the Port Columbus Airport Authority. Creative solutions saved years of remediation and millions of dollars.
- Completed BUSTR Tier 4 RA for American Electric Power.
- Completed Environmental Assessment for NASA - Lewis Rocket Engine Test Facility.
- Completed dozens of Federal/State air, water, and hazardous waste permits (e.g., PTI, PTO, FESOP and NPDES) for dozens of industrial clients.
- Developed Spill Prevention, Controls and Countermeasures (SPCC) Plan template according to 40 CFR 112. Developed SPCC template, which has been audited and accepted by Ohio EPA. Prepared site-specific SPCC's for clients such as L.J. Minor (Cleveland), Mickley Oil Company, Doersam LLC, Federal Express Corporation (Blue Ash), and Central Ohio Asphalt.
- Prepared hazardous waste evaluation for the NASA–Merritt Island Environmental Impact Assessment of Space Shuttle SRB refurbishing facility in a wildlife area.
- Developed a portion of the database used in preparing the original Resource Conservation and Recovery Act (RCRA).
- Developed BUSTR Residential and Commercial Risk Assessment (RA) Models.

Other Experience

- Responsible for all intellectual property (e.g., patents) and commercialization of residential, commercial, vehicle, and fuel cell technology for Columbia Gas System and their development partners.
- Served on 11 Industry Advisory Bodies [Gas Research Institute (GRI), American Gas Association (AGA), U.S. Department of Energy Funding Initiative - $2 billion (USDOE-FI), and Gas Utilization Research Forum (GURF)].
- Served as U.S. DOE expert reviewer on cooling, heat pump, desiccant, and power generation proposals.
- Served on U.S. DOE expert review panel for desiccant program area.
- Prepared business acquisition due diligence for Columbia Gas System corporate staff (e.g. micro-turbines).
- Provided technical and business due diligence for three venture capital firms on a dozen emerging markets.

- Authored budget recommendations for DOE Funding Initiative in Power Generation, Cooling, and NGV areas based on industry consensus meetings.
- Served/Serving on ANSI and ASHRAE Standards Working Groups (Z21.40 and SPC 40).
- Provided keynote presentations on Energy Deregulation for four major utilities and several industry groups.
- Completed nationally recognized market research on U.S. cooling, refrigeration, and controls markets.

Certifications, Registrations, and Honors

Registered Professional Engineer, State of Florida #76583, State of Kentucky #24116, State of Ohio #49063, State of Pennsylvania #PE-053899-E, State of Texas #101855 (also listed windstorm inspector), and State of West Virginia #16311

Certified Industrial Hygienist, 8067 CP, November 2000.

Certified Safety Professional, 23563, November 2012

Asbestos Hazard Evaluation Specialist – State of Ohio #ES34643

Certified Residential Mold Inspector – (IESO) - 2004

ASHRAE Certificate of Appreciation, May 2002, ASHRAE Standard 40.

ASHRAE Fundamentals of HVAC Systems – 35 CEUs (Feb. to April 2008).

AIHA CIH Refresher (Univ. of Michigan) – 40-hr. class - 1998

Certificate of Accomplishment in Risk Assessment from The Ohio State University School of Public Health – 120-hr. class – 1997

Certificate of Achievement – Ohio Department of Transportation 80-hr. class – Managing in the Environmental Process – 1997

Roof Consulting Institute (RCI) Courses:

- Advanced Thermal & Moisture Control (5/14/2008)
- Professional Roof Consulting (5/15-16/2008)
- Roof Technology & Science I (9/15-16/2009)
- Roof Technology & Science II (9/17-18/2009)

Undergraduate Scholarships from the Pulp and Paper Foundation Scholarship Fund for Freshman, Sophomore, and Junior Years.

Certificate of High Scholarship – Department of Chemical Engineering – University of Washington – Jr. Year - 1978.

Undergraduate Scholarship from Department of Chemical Engineering, Senior Year.

Undergraduate B.S. Ch.E. – Cum Laude.

Graduate School - M. S. Ch. E. – 2nd in Class

Raymond Roesch Award, University of Dayton, (awarded annually to top MBA graduate); graduated first in MBA class with 4.0 GPA – 1988.

Memberships

Member, American Industrial Hygiene Association (AIHA)

Member, American Conference of Governmental Industrial Hygienists (ACGIH)

Member, American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). Voting Member TC 8.3.

Member, American Institute of Chemical Engineers (AIChE)

Member, Indoor Environmental Standards Organization (IESO)

Member, Roof Consulting Institute (RCI)

Member, Society of Automotive Engineers (SAE)

Member, Sigma Xi

U.S. Patents

U.S. 6,649,062. November 18, 2003. Fluid-Membrane Separation. Petty.

U.S. 6,109,339. August 29, 2000. Heating System. Talbert, Ball, Yates, Petty, and Grimes.

U.S. 5,769,033. June 23, 1998. Hot Water Storage. Petty and Jones.

U.S. 5,636,527. June 10, 1997. Enhanced Fluid-Liquid Contact. Christensen and Petty.

U.S. 5,546,760. August 20, 1996. Generator Package for Absorption Heat Pumps. Cook, Petty, Meacham, Christensen, and McGahey.

U.S. 5,533,362. July 9, 1996. Heat Transfer Apparatus for Heat Pumps. Cook, Petty, Meacham, Christensen, and McGahey.

U.S. 5,339,654. August 23, 1994. Heat Transfer Apparatus for Heat Pumps. Cook, Petty, Meacham, Christensen, and McGahey.

U.S. 5,067,330. November 26, 1991. Heat Transfer Apparatus for Heat Pumps. Cook, Petty, Meacham, Christensen, and McGahey.

U.S. 4,972,679. November 27, 1990. Absorption Refrigeration and Heat Pump System with Defrost. Petty and Cook.

Books

Forensic Engineering: Damage Assessments for Residential and Commercial Structures, January 4, 2013, CRC Press, 804 pp.

Publications

Stephen E. Petty, 2020, *Visible dust and asbestos: what does it suggest regarding asbestos exposures?* Journal of Scientific Practice and Integrity. 2(1). DOI: 10.35122/001c.14496, August.

Stephen E. Petty, Mark Nicas, Anthony A. Boiarski, 2011. *A quantitative Method for Estimating Dermal Benzene Absorption from Benzene-containing Hydrocarbon Liquids,* Int. J Occup Environ Health, Vol. 17/No. 4, Oct./Dec. 2011, pgs. 287-300.

Stephen E. Petty, PE, CIH, Mark Petty, Tim Kasberg, 2009. *Evaluation of Hail-Strike Damage to Asphalt Shingles Based on Hailstone Size, Roof Pitch, Direction of Incoming Storm, and Facing Roof Elevation*, Interface, The Journal of RCI; May/June, Vol. XXVII, No. 5, pgs. 4-10.

Peter F. Infante, MPH, DRPH, Stephen E. Petty, PE, CIH, D. H. Groth, G. Markowitz, D. Rosner, 2009. *Vinyl Chloride Propellant in Hair Spray and Angiosarcoma of the Liver among Hairdressers and Barbers: Case Reports*, Int. J Occup Environ Health; 15:36-42.

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SUMMARY OF PRESENTATIONS
By
Stephen Petty

DATE	LOCATION	AUDIENCE	TOPIC	DURATION (Hrs)
April 1, 1999	Bureau of Underground Storage Tank Regulators (BUSTR) Reynoldsburg, OH	BUSTR Chief and State Coordinators, Training Session	BUSTR RISK ASSESSMENT TRAINING Introductory Session	8 hours
April 22, 1999	Bureau of Underground Storage Tank Regulators (BUSTR) Reynoldsburg, OH	BUSTR Chief and State Coordinators, Training Session	BUSTR RISK ASSESSMENT TRAINING Second Session	8 hours
May 6, 1999	Bureau of Underground Storage Tank Regulators (BUSTR) Reynoldsburg, OH	BUSTR Chief and State Coordinators, Training Session	BUSTR RISK ASSESSMENT TRAINING Third Session	8 hours
May 27, 1999	Bureau of Underground Storage Tank Regulators (BUSTR) Reynoldsburg, OH	BUSTR Chief and State Coordinators, Training Session	BUSTR RISK ASSESSMENT TRAINING Fourth Session	8 hours
June 4, 1999	Bureau of Underground Storage Tank Regulators (BUSTR) Reynoldsburg, OH	BUSTR Chief and State Coordinators, Training Session	BUSTR RISK ASSESSMENT TRAINING Fifth Session	8 hours
May 23, 2000	Bureau of Underground Storage Tank Regulators (BUSTR) Reynoldsburg, OH	BUSTR Chief and State Coordinators, Training Session	Factors Influencing Tier 1 and Tier 2 Evaluations Training Session for New Rules	8 hours
January 18, 2001	Engineer's Club, Dayton, OH	ASHRAE, Dayton Chapter, Dinner Speaker	Energy and Cost Benefit Analyses of Heating, Ventilation and Air Conditioning Systems Available for Ohio Schools	2 hours

DATE	LOCATION	AUDIENCE	TOPIC	DURATION (Hrs)
January 25, 2001	Riffe Tower, Columbus, OH	Ohio School Facilities Commission, Ohio Department of Development, State School A/Es	Energy and Cost Benefit Analyses of Heating, Ventilation and Air Conditioning Systems Available for Ohio Schools	7 hours
March 13, 2001	Ashland Chemical, Columbus, OH	PDMA – Columbus Chapter, Breakfast Speaker	The Product Development Process - Case Studies	1 hour
July 30, 2001	Toledo, OH	City of Toledo, Environmental Director and Staff	Status of BUSTR's New Rule, March 31, 1999	2 hours
September 21, 2001	Lexington, KY	ASHRAE Region VII & Bluegrass Chapter, Invited Luncheon Speaker	Energy and Cost Benefit Analyses of Heating, Ventilation and Air Conditioning Systems Available for Ohio Schools	1.5 hour
November 13, 2001	Wadsworth, OH	ASHRAE Akron Chapter, Dinner Speaker	Energy and Cost Benefit Analyses of Heating, Ventilation and Air Conditioning Systems Available for Ohio Schools	2 hours
February 12, 2002	Cincinnati, OH	ASHRAE Cincinnati Chapter, Lunch Speaker	Evaluation of Heating, Ventilation and Air Conditioning Systems (HVAC) Systems Available for Ohio Schools	1.5 hours
July 2002	Cleveland, OH	AIHA Luncheon Speaker	IAQ Cost – Benefit Analyses For Heating, Ventilation and Air Conditioning Systems (HVAC) Systems Available for Ohio Schools	1.5 hours
September 24, 2002	Columbus, OH	Ohio Builds 2002	Evaluation of HVAC Systems Contained in the OSFC Design Manual	1.5 hours
February 5, 2003	Toledo, OH	ASHRAE Toledo Chapter, Dinner Speaker	Energy and Cost Benefit Analyses of Heating, Ventilation and Air Conditioning Systems Available for Ohio Schools	2 hours
May 9, 2004	Atlanta, GA	American Industrial Hygiene Conference and Expo (AIHce), Professional Development Course #418	Mold Contamination: A Hands-On Workshop Addressing Inspection, Remediation Specifications, Project Oversight and Post-Remediation Assessment	8 hours
September 14, 2004	Gahanna, OH	Gahanna Board of Realtors Luncheon Speaker	Mold – After the Contract	1 hour

DATE	LOCATION	AUDIENCE	TOPIC	DURATION (Hrs)
November 4, 2004	Cincinnati, OH	Cincinnati Bar Association Luncheon Speaker	Mold – Facts/Fiction/Who Knows?	2 hours
November 17, 2004	Columbus, OH	Ohio Public Facility Maintenance Association (OPFMA) Annual Meeting	Impact of Temperature on Occupants: Theory vs. Reality	1.5 hours
October 17, 2005	Phoenix, AZ	LexisNexis Benzene Litigation Conference	How Low Can You Go? Measuring Exposure to Benzene	1 hour
April 21, 2006	Cleveland, OH	National Business Institute Proving Damages Caused by Mold Infestation in Ohio	Make a Mold Claim and Litigate the Case	2 hours
November 9, 2006	Columbus, OH	Bricker & Eckler Building Industry	Avoiding and Handling Mold Claims	1 hour
June 3, 2008	New Orleans, LA	Harris-Martin Benzene Conference	Historic Levels of Benzene in Products	1 hour
August 14, 2009	Columbus, OH	State Auto Insurance Company	Assessment of Hail and Wind Damage	3 hours
December 4, 2009	Akron, OH	Nationwide Insurance Company	Presentation and Seminar on Log Cabin Construction, Maintenance & Reparability	2 hours
March 17, 2010	Westerville, OH	Nationwide Insurance Company	Seminar on Impact of Wind & Hail Damage to Building Materials	1 hour
May 9, 2012	Dublin, OH	Grange Insurance Company	Lightning Damage Assessments	3 hours
June 18, 2013	Delaware, OH	Nationwide Insurance Company	Forensic Analysis of Fire Damage to Foundation Walls	3 hours

SUMMARY OF CLASSES TAUGHT AT FRANKLIN UNIVERSITY

By

Stephen Petty

Class Title	Description	Term	Dates	# Students	Comments
SCIE131 Q1WW	Environmental Science 131	Winter 2003	1/3/03 to 4/24/03	17	Online class
SCIE131 E1FF	Environmental Science 131	Summer 2003	5/21/03 to 6/25/03	13	In-Class
SCIE114 F2FF	Earth Science 114	Fall 2003	9/29/03 to 11/3/03	17	In-Class
SCIE131 H1FF	Environmental Science 131	Fall 2003	11/12/03 to 12/17/03	15	In-Class
SCIE131 Q1WW	Environmental Science 131	Summer 2004	05/17/04 to 08/07/04	14	Online class
SCIE131 H1FF	Environmental Science 131	Fall 2004	11/10/04 to 12/15/04	19	In-Class
SCIE 131 H1FF	Environmental Science 131	Fall 2005	11/9/05 to 12/14/05	19	In-Class
SCIE 131 H1FF	Environmental Science 131	Spring 2006	3/27/06 to 5/1/06	?	In-Class

SCIE 114 – 4 Semester Credit Hours

SCIE 131 – 4 Semester Credit Hours

EXHIBIT ii

SUMMARY OF EXPERT WITNESS CASES – STEPHEN PETTY

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Luther L. Liggett Jr. Bricker & Eckler, L.L.P. 100 S. Third Street Columbus, OH 43215	Construction Corporation vs. Roth Produce (Supported Plaintiff). Testified at hearing in Franklin County, OH.	Refrigerated Warehouse (Design Purpose – HVAC) Testified at Mediation Hearing	Settled in Arbitration	- / -	2001
Mr. Michael P. Giertz Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Sandra D. Howell and Estate of Mr. Howell Defendant(s): Nalco, Bayer and David Hackathorn (Bayer's Director of Health) In the Circuit Court of Marshall County, West Virginia (Supported Plaintiffs)	Legionella Exposure at Chemical Plant Deposed by Defendant(s) 2003	Negotiated Settlement	EES-2002-002 Case No. 00-C-234M	2002
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Donna E. Gwinn, Individually and Executrix of the Estate of William B. Gwinn Defendant(s): Chemical Leaman Tank Lines (CLTL), a Delaware Corporation, Quality Distribution, Inc., d/b/a Quality Carrier, Successor-in-Interest to Chemical Leaman Tank Lines, Inc., a Florida Corporation, and Okey Edens. In the Circuit Court of Marshall County, West Virginia. (Supported Plaintiffs).	Benzene Exposure at Tanker Truck Cleaning Facility Deposed on 3/21/2003	Negotiated Settlement	EES-2002-040 Case No. 02-C-120M	2002-2003
Mr. Guy Bucci Attorney at Law Bucci, Bailey & Javins P. O. Box 3712 Charleston, West Virginia 25337	Plaintiff(s): William Shaffer and Rosa Shaffer, husband and wife. Defendant(s): Monongahela Power Company d/b/a Allegheny Power as an Ohio Corporation In the Circuit Court of Pleasants County, West Virginia (Supported Plaintiff)	Legionella Exposure at Power Plant Settled 04/2004	Negotiated Settlement	EES-2002-01 Cause No.: 00 -C-28	2001 - 2004
Mr. James M. Barber Attorney at Law 604 Virginia Street, East Suite 200 Charleston, WV 25301	Plaintiff(s): Daniel O. Dixon Defendant(s): A C & S, Inc. (Supported Plaintiff)	Acid Gas Exposure at Chemical Plant Settled 05/2004	Negotiated Settlement	EES-2003-005 Cause No.: 02-C-1995	2003 - 2004
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Michael A. Lebron, Pamela Lebron Defendant(s): Shell Oil Company; Amoco Oil Company; Union Oil Company of California; Radiator Specialty Company; PPG Industries, Inc.; E.I. Du Pont de Nemours & Company and Bondo Corporation. (Supported Plaintiffs)	Benzene Exposure from Paint and Service Station Operations Deposed by Defendant(s) on 11/21/03	Negotiated Settlement 03/2009	EES-2002-052 Cause No.: 01L10021	2002-2009

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Brian Bradigan Attorney At Law Brian J. Bradigan, L.L.C. 3948 Townsfair Way Suite 230 Columbus, OH 43219	Plaintiff(s): Jeffrey and Theresa Vaughn (Homeowners) Defendant(s): Timberline Log Homes (Grange Insurance – Builder's Insurance) (Supported Defendant)	Mold and Water Leaks in Log Home Due to Poor Construction	Negotiated Settlement	EES-2003-019 -	2003
Ms. Joanne Peters Attorney At Law Isaac, Brant, Ledman & Teetor LLP 250 E. Broad St. Suite 900 Columbus, OH 43215-3742	Plaintiff(s): Fisher (Homeowners) Defendant(s): Muth and Company – Roofing Company (Supported Defendant)	Mold and Water Leaks in Home Due to Roof Installation	Negotiated Settlement	- / -	2003
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Timothy J. Farley Defendant(s): Keystone Shipping Company, Margate Shipping Company and Chilbar Shipping Company Shipping Company Court of Common Pleas Philadelphia County, PA Civil Action - Law (Supported Plaintiff)	Benzene and other Chemical Exposures from Working on Tankers	Negotiated Settlement 8/09/2004	EES-2003-180 Cause No.: 0957	2003-2004
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): David Ball Defendant(s): BASF, Corp., Ford Motor Company, 3M Company, Petroleum Traders Company, Myers Industries, Inc., d/b/a Patch Rubber Co., Radiator Specialty Company, Loctite Corporation, and Lykins Oil Company Court of Common Pleas Cuyahoga, Ohio (Supported Plaintiff)	Benzene and other Chemical Exposures Focus on Labeling and MSDS sheets	Negotiated Settlement 12/2005	EES-2003-217 Cause No.: CV-02-473352	2003-2005
Voltolini & Voltolini Attorneys at Law 1350 West Fifth Ave. Suite 214 Columbus, OH 43212	Plaintiff: Janis Weekly Defendant(s): Terminix Pre-Lawsuit (Supported Plaintiff)	Durisban - Chlorpyrifos (Pesticide) Exposure Completed detailed inspection and research.	Completed	EES-2003-352 Cause No: 94-018	2003-2004
Harvit & Schwartz, L.C. 2018 Kanawha Blvd., E. Charleston, WV 25311	Plaintiff: Robert H. Casdorph, Jr and Melba Casdorph, his wife Defendant(s): West Virginia State Police, an agency of the State of West Virginia, and Castle Products, Inc., a New York Corporation. In the Circuit Court of Marshall County, West Virginia (Supported Plaintiff)	CML-Chronic Myelogenous Leukemia	Negotiated Settlement 11/2011	EES-2003-329 Cause No.: 03-C-109M Worker's Comp. Decision Appealed to WV Supreme Ct. – Decision in	2003-2011

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
				Favor of Plaintiff on 11/9/2019	
Dinsmore & Shohl, LLP 255 E. Fifth Street, Suite 1900 Cincinnati, OH 45202	Plaintiff: Doug Kinslow Defendant(s): M.E.B. Two (Supported Defendant)	Mold Contamination Inspection, mold testing and detailed findings report	Negotiated Settlement	EES-2003-353 Cause No.: 3780-88	2003-2004
Mr. Scott Sheets Attorney At Law Isaac, Brant, Ledman & Teetor LLP 250 E. Broad St., Suite 900 Columbus, OH 43215-3742	Plaintiff: Stanger (Homeowners) Defendant(s): Davis Fine Homes – Homebuilder (Supported Plaintiff)	Mold and Water Inspection, Testing, and Support	Negotiated Settlement	EES-2003-366	2003
Mr. J. Andrew Crawford Reese, Pyle, Drake & Meyer, P.L.L. 36 N. Second Street P.O. Box 919 Newark, OH 43058-0919	Plaintiff: Murray Headlee et al. Defendant(s): Truberry Group, Inc. et al. (Homebuilder) Delaware, OH County Court of Common Pleas (Supported Defendant)	Mold and Water Leaks in Home; Prepared outline of opinions.	Negotiated Settlement on/about 03/08/2004	EES-2003-405 Cause No.: 03 CVH 01007	2003 - 2004
Mr. J. Zackary Zatezalo Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Mr. James V. Dollhopf and Kristin L. Dollhopf Defendant(s): PPG Industries, Sherwin-Williams Company, Ashland, Inc., CIBA Specialty Chemicals, Chem-Pak Solutions, General Fiberglass Supply, Inc., Meguiar's Products, Sunnyside Corporation, Milwaukee Paint, Inc. State of Wisconsin Circuit Court Milwaukee County (Supported Plaintiff)	Benzene and other Chemical Exposures from Painting Operations	Negotiated Settlement	EES-2003-407 Cause No.: 03-CV-4832	2003-2004
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Shelly Gray, Individually and as Plaintiff Ad Litem for Sherri Bond, deceased. Defendant(s): BP Corporation North America Inc. and BP Products North America Inc. et.al – Former American Oil Company (AMOCO) Site Circuit Court of Jackson County, Missouri, at Independence. (Supported Plaintiff)	Benzene and other Chemical Exposures from Underground Piping and Tank Leaks	Negotiated Settlement 03/16/2006	EES-2003-415 Case No.: 02-CV-229538	2003-2006
Mr. J. Michael Prascik Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600, Wheeling, WV 26003	Plaintiff: Mr. Barry Hovis and Lesa Hovis, his wife. Defendant(s): Carboline Company, Rust-Oleum Corporation, E.I. Dupont De Nemours and Company, Valspar Coatings, One Shot, LLC, PPG Industries, Inc., Sherwin-Williams, . In the Circuit Court of Common Pleas in York County, South Carolina. (Supported Plaintiff)	Exposure to Paint	Negotiated Settlement 10/2004	EES-2004-049 Cause No.: 2003-CP-46-165	2004
Mr. J. Michael Prascik Hartley & O'Brien, P.L.L.C. The Wagner Building	Plaintiff: Lucinda Cutlip Defendant(s): West Virginia Department of Transportation, Division of Highways, and Guttman Oil Company, a foreign	Exposure to Diesel Exhaust	Testified in Trial 1/10/06	EES-2004-066	2004-2006

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
2001 Main Street, Suite 600, Wheeling, WV 26003	corporation In the Circuit Court of Kanawha County West Virginia (Supported Plaintiff)	Deposed by Defendant(s) on 08/11/2005 and 09/21/2005	Decision in Favor of Defendant	Cause No.: 02-C-2345	
Mr. Kris Cormany Attorney at Law Bucci, Bailey & Javins P. O. Box 3712 Charleston, West Virginia 25337	Plaintiff: Erby E. Lester and Donna Lester, his wife Defendant(s): Elk Run Coal Company, Inc. a West Virginia Corporation d/b/a Black Castle Mining Company, Spartan Mining Company, a West Virginia Corporation and d/b/a Trace Transport Company. In the Circuit Court of Boone County West Virginia. (Supported Plaintiff)	Exposure to Combustion Products From Fire in Maintenance Building Deposed by Defendant on 03/01/2006	Negotiated Settlement 05/10/2006	LAW-2004-009 Cause No.: 04-C-231	2004 - 2006
Mr. Guy R. Bucci Bucci Bailey & Javins Suite 910 Bank One Center, 707 Virginia Street, East, Charleston, WV 25301	Plaintiff: Linda Kitzmiller Defendant(s): Jefferson Supply Co. United States District Court For the Northern District of West Virginia, Elkins Division (Supported Plaintiff)	Exposure to Chemicals Deposed by Defendant(s) 06/06/2006 Daubert Hearing 10/30/2006 – Motion Denied	Negotiated Settlement 11/05/2007	LAW-2004-010 Cause No.: 2:05-CV-22	2004 - 2007
Mr. Chris Wilson Wilson, Frame, Benninger & Metheney, P.L.L.C.	Plaintiff: Paula J. Ondo Defendant(s): TBD (Supported Plaintiff)	Mold and HVAC	Completed Report Submitted	EES-2004-134	2004
Mr. J. Michael Prascik Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Mr. Douglas Bates Defendant(s): The Dow Chemical Company et al. (Supported Plaintiff)	Chemical Exposure - Various products in garage	Closed	EES-2004-137 Cause No.: 3:03CV519BN	2005-2009
Mr. J. Michael Prascik Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600, Wheeling, WV 26003	Plaintiff: Deborah Trojan Defendant(s): Peoples Gas Light & Coke Co. (Supported Plaintiff)	Benzene Exposure From Former Manufactured Gas Plant Site Deposed by Defendant 11/12/2004	Negotiated Settlement 12/2004	EES-2004-135 Cause No.: 01 L 16472	2004

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Charles Cooper Charles Cooper Law Offices 407 Center Street Ironton, OH 45638	Plaintiff: Mr. and Mrs. Shelton Defendant(s): Mr. and Mrs. LeMaster (Supported Plaintiff) In response to Grange Claim #: HP91871 (Supported Defendant)	Mold and Water Damage	Closed	LAW-2004-004	2004-2005
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Mr. Robert Scherer Defendant(s): S & S Automotive, Inc. et al. (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 11/11/2004	Negotiated Settlement 11/2005	LAW-2004-001 Cause No.: 02 L 435	2004-2005
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Mr. Earl Douglas Defendant(s): Ashland, Inc. et al. (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 03/29/2005 Daubert Hearing 01/13/2006 – Motion Denied	Negotiated Settlement 04/2008	LAW-2004-002 Cause No.: 01/CE-00392	2004-2008
Mr. Guy R. Bucci Bucci Bailey & Javins Suite 910 Bank One Center, 707 Virginia Street, East, Charleston, WV 25301	Plaintiff: Brummage et al. Defendant(s): Thrasher et al. (Supported Plaintiff)	Mold and Bacteria Exposures/Sewage System Failure (Two expert reports written late 2004 and early 2005).	Negotiated Settlement 09/2005	LAW-2004-003	2004-2005
Mr. William M. Owens Owens & Manning 413 Main Street, 2nd Floor Coshocton, OH 43812	Plaintiff: Ms. Delaine Freeman Defendant(s): Randy Stotts et al. (Supported Plaintiff)	Mold Determination	Negotiated Settlement 10/2004	LAW-2004-005 Cause No.: 02 CI 588	2004
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Mr. Terry Defendant(s): Go-Mart Inc. et al. (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 8/20/2009	Negotiated Settlement 9/2010	LAW-2004-006	2004-2010
Mr. David J. Romano Romano Law Office 363 Washington Avenue Clarksburg, WV 26301	Plaintiff; Cathy A. Arnett Representative of John P. Arnett (Deceased) Defendant(s); The Marmon Corporation et al. (Supported Plaintiff)	Hazardous Chemical Exposure – Cleaners with Sodium Hydroxide	Negotiated Settlement 02/14/2005	LAW-2004-007 Cause No.: 03-C-570-2	2004 - 2005

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Stephen Brown Mundy & Nelson, L.L.C. P.O. Box 2986 Huntington, WV 25728	Plaintiffs: TBD – Citizens of Huntington Defendant: TechSol (Supported Plaintiff)	Hazardous Chemical Exposure – Coal Tar Containing Benzene – Sampled Creek and Homes for VOCs	Negotiated Settlement 11/2006	LAW-2004-011	2004 - 2005
Mr. Paul Eklund Davis & Young 1700 Midland Building 101 Prospect Avenue West Cleveland, OH 44115-1027	Plaintiffs: Enrico M. Clark and Cynthia Clark Defendant(s): Alchem Corporation and B. George Bufkin (Supported Defendant)	Hazardous Chemical Exposure – Methanol and Acid Gases	Negotiated Settlement 07/2006	LAW-2004-014 Cause No.: 528128	2004 - 2006
Mr. Brian Bradigan Attorney At Law Brian J. Bradigan, L.L.C. 3948 Townsfair Way, Suite 230 Columbus, OH 43219	Plaintiffs: Wanner Searls (Homeowner) Defendant(s): Grange Mutual Casualty Company Franklin County Ohio Court of Common Pleas (Supported Defendant)	Hail Damage to Home	Testified in Trial 04/18/2005 Decision in Favor of Defendant(s) 05/31/2005	EES-2004-094	2004 - 2005
Mr. Lon Walters Partner The Walters Law Firm The Oldham Building 105 East 5th Street Suite 401 Kansas City, MO 64106	Plaintiff: Estate of Nancy Ryan Defendant(s): BP Corporation, American Oil Company, et al. Circuit Court of Jackson County, Independence, MO (Supported Plaintiff)	Benzene/Chemical Exposures from Underground Piping and Tank Leaks and Vapor Emissions	Testified in Trial 08/24-25/2005 Jury Ruled in Favor of Plaintiff(s) – 09/14/2005	LAW-2004-012 Cause No.: 04CV223271	2004 - 2005
Mr. John Davis Gallaghar, Sharp, Fulton & Norman 1501 Euclid Avenue, Seventh Floor Cleveland, OH 44115 Mr. Charles Williams 555 South Front Street, Suite 320 Columbus, OH 43215	Plaintiff: Hidden Lakes Condominium Association Defendant: Acuity Insurance Company (Umpire – Supported Defendant)	Hail Damage Appraisal Umpire Claim #: KL3009 Umpired Decision and Report Issued 04/2005	Completed	EES-2005-020-S	2005
Mr. Nicholas Subashi Subashi, Wildermuth & Ballato The Oakwood Building 2305 Far Hills Avenue Dayton, OH 45419 Mr. Randall Saunders Nationwide Insurance Company 620 Morrison Road Gahanna, OH 43230	Plaintiff: James Wilson et al. Defendant: STO Corp., Jack H. Wieland Builders, Daytco-James, Inc. et al. (Supported Defendant – Roofing Contractor)	Construction Defect Claims Claim #: 92 34 AC 324909 03011997 51 Provided Inspection, Analysis and 3 reports on liability of roofing contractor.	Completed Negotiated Settlement 06/30/2005	EES-2005-050-S Cause No.: 03 CV 61596	2005

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. James M. Barber Attorney at Law 604 Virginia Street, East Suite 200 Charleston, WV 25301	Plaintiff: Lola Hudson Defendant: Arbors Management and Rock Branch Mechanical (Supported Plaintiff)	Legionella Exposure Deposed 12/13/2005	Closed	Law-2005-001	2005 - 2006
Mr. J. Zachary Zatezalo Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Little Defendant: American Electric Power (Supported Plaintiff)	Solvent Exposure Deposed by Defendant 03/25/2011	Negotiated Settlement 2011	LAW-2005-002 Cause No.: 03-C-256M	2005-2011
Mr. Guy R. Bucci Bucci Bailey & Javins Suite 910 Bank One Center, 707 Virginia Street, East, Charleston, WV 25301	Plaintiff: Mr. Daniel A. Wilson and Mrs. Joyce L. Wilson Defendant: Mr. Raymond Johnson d/b/a Ray's Auto Center (Supported Plaintiff)	Hazardous Chemicals Exposure	Closed	LAW-2005-006 Cause No.: 04-C-232	2005-2007
Mr. Michael P. Giertz Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Janice Weekley Defendant: Terminix International Company (Supported Plaintiff)	Property Contamination from Termidicides (Pesticides) Deposed by Defendant 09/09/2005	Negotiated Settlement 11/2005	LAW-2005-007 Cause No.: 52-181-00697-04	2005
Mr. Bradley R. Oldaker Bailey, Stultz, Oldaker & Greene P.O. Drawer 1310 Weston, WV 26452-1310	Plaintiff: Mack O. Crist Defendant: Vicellio & Grogan et al. (Supported Plaintiff)	Silica- Exposure – Highway Construction Deposed by Defendant 01/17/2006	Negotiated Settlement 05/2006	LAW-2005-008 Cause No.: 04C-64M	2005-2006
Mr. J. Zachary Zatezalo Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Jayne Chianelli and estate of Frank Chianelli Defendant(s): Shell Oil Company, Potter Paint Co., Mohawk Finishing Products, Phipps Products Corp., BIX Manufacturing Company, Sherwin Williams Company, Barnett Industries and E.E. Zimmerman (Supported Plaintiff)	Solvent Exposure	Negotiated Settlement 2006	LAW-2005-009 Cause No.: 03 12999/	2005-2006
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Denny Morris Defendant: PPG Industries, Inc. (Supported Plaintiff)	Benzene Exposure Deposed by Defendant 10/12/2005	Closed	LAW-2005-010 Cause No.: 99-C-173M	2005-2009

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building Suite 600 2001 Main Street, Wheeling, WV 26003	Plaintiff: Thomas H. Ware and Pamela S. Ware, his wife Defendant: Pratt & Whitney Engine Services, Inc. In the Circuit Court of Harrison County, West Virginia (Supported Plaintiff)	Hazardous Chemicals Exposure	Negotiated Settlement 01/2006	LAW-2005-011 Cause No.: 05-C-139-1	2005-2006
Ms. Sandra Spurgeon Spurgeon & Tinker, PSC 120 Prosperous Place, Suite 202 Lexington, KY 40509	Robert A. Tompkins, et al v. Wheeling-Pittsburgh Steel Corporation d/b/a Wheeling Corrugating Company, Inc., et. al v. Terry Roland (Supported Defendant - Insurance Company)	Exposure	Closed	LAW-2005-013	2005-2008
Mr. Louis H. Watson, Jr., P.A. Attorney at Law 520 Capitol Street Jackson, Mississippi 39201-2703	Plaintiff: Fay Lundy and Joel Lundy Defendant: Cilburn Truck Lines, Inc., Conoco, Inc., Individually, a/k/a Conoco Gas and Marketing, a Division of Conoco, Inc., and f/k/a Du Pont Holdings, Inc; ConcoPhillips Company; "John Doe" Defendant(s) In the United States District Court for the Southern District of Mississippi Jackson Division (Supported Plaintiff)	Exposure to benzene from gasoline Deposed by Defendant 9/20/2006	Negotiated Settlement	LAW-2005-014 2005-16 Case No. 2005-16	2005-2007
Mr. Michael P. Giertz Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Pauline Poling Defendant: Grafton Auto Parts Circuit Court of Marshall County, West Virginia (Supported Plaintiff)	Exposure to Benzene Containing Solvents	Negotiated Settlement	LAW-2005-016 Case #: 05-C-157M	2005-2009
Mr. Thomas E. Schwartz Holloran White & Schwartz LLP 2000 S. 8th Street St. Louis, Missouri 63104	Plaintiff: Jeff Morgan Defendant: National Railroad Passenger Corporation (Supported Plaintiff)	Diesel Exhaust Exposure Deposed by Defendant 01/31/2006	Negotiated Settlement 04/28/2006	LAW-2005-018 Cause No.: 052-08718	2005-2006
Mr. Richard A. LaVerdiere Sieben Polk LaVerdiere & Dusich 999 Westview Drive Hastings, MN 55033-2495	Plaintiff: Vettrus Defendant: Ashland Chemical et al. Third Judicial District Court, County of Rice, MN (Supported Plaintiff)	Exposure to solvents containing benzene Deposed by Defendant(s) 03/20/2007	Closed	LAW-2005-019 C5-05-1909	2005-2008
Mr. Kevin George 931 Vauxhill Lane Powell, OH 43065	Plaintiff: Mallory Pools Defendant: Mr. Kevin George Delaware County, Ohio Court of Common Pleas (Supported Defendant)	Pool chemistry and staining on Liner. Testified in Trial (Delaware County Court) 01/19/2006	Decision in favor of Defendant	EES-2006-166	2005-2006
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100	Plaintiff: Benoit Defendant: Ato Fina et al.	Exposure to benzene and benzene containing solvents in	Closed	LAW-2005-020	2005-2007

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Dallas, TX 75219	18th Judicial District Court, For the Parish of Iberville, State of Louisiana (Supported Plaintiff)	refineries and chemical plants		Cause No.: 62116, Div. A	
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiffs: Stubbs & Wilkinson (two cases). Ms. Ann Stubbs, representing the estate of Ben L. Stubbs Herbert W. Wilkinson and Peggy S. Hebert Defendant(s): Radiator Specialty Company et al. 128th Judicial District Court, Orange County, TX (Supported Plaintiff)	Exposure to benzene & benzene-containing solvents- refineries, chemical plants Deposed by Defendant(s) 3/29/06 and 4/25/06	Negotiated Settlement	LAW-2005-021 & BAR-2006-001 Stubbs/Wilkinson - Cause No.:A-030272C	2005-2007
Mr. Thomas E. Schwartz Holloran White & Schwartz LLP 2000 S. 8th Street St. Louis, Missouri 63104	Plaintiff: Ursula Michelle Creaghan and Daniel Aaron Creaghan as surviving children of Steven Francis Creaghan Defendant: Superior Solvents & Chemicals, Inc.; Transchemical Inc., Ashland, Inc., Chemisphere Corp., Reichhold, Inc. Akzo Nobel Coatings, Inc., Brenntag Mid-South, Inc., Eastman Chemical Co., and Shell Oil Company (Supported Plaintiff)	Benzene exposure from paint manufacturing Deposed by Defendant on 8/29/2006	Negotiated Settlement 9/2006	LAW-2005-022 Cause No.: 042-07417	2005-2007
Mr. Lon Walters The Walters Law Firm The Oldham Building 105 East 5th Street, Suite 401 Kansas City, MO 64106	Plaintiff: Detel Defendant: BP Corporation North America, Inc., and BP Products North America, Inc. Circuit Court of Jackson County, Independence, MO (Supported Plaintiff)	Benzene exposure Deposed by Defendant on 9/11/2006	Negotiated Settlement 10/18/2006	WAL-06-001 Cause No.: 04CV207637	2005-2006
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Richard C. Smith and Vickie Smith Defendant(s): Sal Chemical Company, Inc., Chemical Solvents, Inc., and United States Can Company Circuit Court of Brooke County, WV (Supported Plaintiff)	Organic Chemical Exposure Deposed by Defendant(s) 02/06/2007	Negotiated Settlement 06/2007	HAR-2006-002 Case No.: 05-C-211 AMR	2006-2007
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiffs: Troy Lucas Defendant(s): Diamond Shamrock, Marathon, U.S. Steel, WD-40, Radiator Specialty, ConocoPhillips and Occidental Chemical 23rd Judicial District Court, Brazoria County, TX (Supported Plaintiff)	Exposure to benzene and benzene containing solvents while working for Diamond Shamrock	Closed	BAR-2006-002 Cause No. 35,311	2006-2007
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiffs: Donna Cashiola, Page Defendant(s): American Petroleum Institute, Inc. et al. 298th Judicial Court, Dallas, TX (Supported Plaintiff)	Exposure Deposed by Defendant 9/22/2006	Decision in favor of Defendant	BAR-2006-005 Cause No.: 04-00545	2006-2008

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiff: David Carpenter Defendant(s): Spray Products Corp. et al. Circuit Court of Cook County, Chicago, Illinois (Supported Plaintiff)	Benzene Exposure	2007	BAR-2006-006 Cause No.: 2006L00673	2006-2007
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiffs: Larry Koger (deceased) and Kim Koger Defendant(s): Ashburn Industries et al. 128th Judicial District Court, Orange County, TX (Supported Plaintiff)	Exposure to benzene and benzene containing solvents while working for EBBA Iron	Negotiated Settlement	BAR-2006-007 Cause No.: A050388-C	2006-2007
Mr. Kirk Claunch Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiffs: Bekkelund Defendant(s): General Tire, Shell, Specialty Radiator 23rd Judicial District Court, Brazoria County, TX (Supported Plaintiff)	Exposure to benzene and benzene containing solvents Deposed by Defendant 3/13/2007	Negotiated Settlement	BAR-2006-009 Cause No.: 24038*BJ03	2006-2008
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff: Kirk Jenkins Defendant(s): (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 2008	LOC-2006-001	2006-2008
Mr. Bradley Oldaker Bailey, Stultz, Oldaker & Green P.O. Drawer 1310 Weston, West Virginia 26452	Plaintiffs: William K. Stern et al. Defendant(s): Chemtal Incorporated et al. Circuit Court of Marshall County, West Virginia (Supported Plaintiff)	Exposure to Polyacrylamide Flocculant with Residual Acrylamide Monomer.	Negotiated Settlement	OLD-2007-001 Cause No.: 03-C-49M	2004
Mr. Lon Walters The Walters Law Firm The Oldham Building 105 East 5th Street, Suite 401 Kansas City, MO 64106	Plaintiff: Sean Reed Defendant(s): B.P. Corporation North America, Inc., and BP Products North America, Inc. et al. Circuit Court of Jackson County, Missouri at Independence (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement	WAL-2007-001 Cause No.: 04CV-209341	2007
Mr. John Hughes The Law Offices of John J. Hughes 1200 Gough Street, Suite 1 San Francisco, CA 94109	Plaintiff: Daniel F. Dean as administrator of the estate of William J. Dean Defendant(s): Overseas Shipbuilding Group (OSG) Ship Management, Inc., Juneau Tanker Group, Inc., Cambridge Tankers, Inc., OMI Corp., Interocean Ugland Management, Inc., and SL Service, Inc. Superior Court of the State of California, County of San Francisco (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 04/2008	HUG-2007-001 Cause No.: CGC-04-430986	2007-2008
Mr. Jim Waldenberger Kline & Specter The Nineteenth Floor	Plaintiff: Karen Horvat, Estate of Andrew J. Horvat, Deceased, et al.	Benzene Exposure	Negotiated Settlement	WAL-2007-001	2007-2012

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
1525 Locust Street Philadelphia, PN 19102	Defendant(s): Crane Oil Company et al. Superior Court of New Jersey Gloucester County (Supported Plaintiff)		01/2012	Cause No.: GLO-000497-07	
Mr. J. Keith Hyde **Ms. D'Juana Parks** Provost & Umphrey, L.L.P. 490 Park Street P.O. Box 4905 Beaumont, TX 77704	Plaintiff: Jan Goss, Individually and as Representative of the Estate of Velma Church, Deceased, et al. Defendant: Schering-Plough Corp. 4th Judicial Court, Rusk County, State of Texas (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 04/2008	PAR-2007-001 Cause No.: 2006-232	2007-2008
Bradley R. Oldaker Bailey, Stultz, Oldaker & Greene P.O. Drawer 1310 Weston, West Virginia 26452	Plaintiff: Estate of Darren Patrick Brake Defendant: TKS Contracting Circuit Court of Upshur County, West Virginia (Supported Plaintiff)	Wrongful Death Forklift Accident	Negotiated Settlement 02/2008	OLD-2007-002 Case No.: 07-C-155	2007-2008
Mr. John Langdoc Baron & Bud Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiff: Edward Paul Wick Defendant(s): 3M Company et al. Court of Common Pleas Philadelphia County (Supported Plaintiff)	Asbestos	Negotiated Settlement 02/2009	BAR-2007-004 Cause No.: 0512-2989	2007-2009
Mr. Lon Walters The Walters Law Firm The Oldham Building 105 East 5th Street, Suite 401 Kansas City, MO 64106	Plaintiff: Paul Hedrick & Joyce Hedrick Defendant: BP Corporation North America Inc. and BP Products North America Inc. – Former American Oil Company (AMOCO) Site Circuit Court of Jackson County, Missouri at Independence (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement	LON-2007-002 Cause No.: 04CV-209360 – Div. 16	2007
Mr. Lon Walters The Walters Law Firm The Oldham Building 105 East 5th Street, Suite 401 Kansas City, MO 64106	Plaintiff: Barbara Behymer, individually and as Plaintiff Ad Litem for Richard Behymer, deceased Defendant: BP Corporation North America Inc. and BP Products North America Inc. – Former American Oil Company (AMOCO) Site. Circuit Court of Jackson County, Missouri at Independence. (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 03/07/2008	LON-2007-003 Cause No.: 04CV238342	2007-2008
Mr. Chuck Gordon **Hubbell Peak O'Neal Napier &** Leach Law Firm Union Station 30 W. Pershing Rd., Suite 350 Kansas City, MO 64108	Plaintiff: Robert L. Almaguer Defendant: The Burlington Northern & Santa Fe Railway Company City Court of the City of St. Louis, State of Missouri (Supported Plaintiff)	Railroad Worker PAH Exposure	Negotiated Settlement 08/16/2008	HUB-2007-001 Cause No.: 052-10081	2007-2008
Mr. Gregory A. Lofstead Richardson, Patrick, Westbrook & Brickman, LLC 174 East Bay Street Charleston SC 29401	Plaintiff: Dennie Polk Defendant: Brooks Run Coal Company et al. Circuit Court of Mingo County, West Virginia (Supported Plaintiff)	Silicosis	Negotiated Settlement 01/2008	RPWB-2007-001 Cause No.: 04-C-650	2007-2008

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Gregory A. Lofstead Richardson, Patrick, Westbrook & Brickman, LLC 174 East Bay Street Charleston SC 29401	Plaintiff: Ricky G. Prince and Diana Prince Defendant: Eastern Associated Coal Corp. et al. Circuit Court of Mingo County, West Virginia (Supported Plaintiff)	Silicosis	Negotiated Settlement 05/2008	RPWB-2007-002 Cause No.: 04-C-289	2007-2008
Mr. James Zury The Law Offices of James C. Zury 450 Alkyre Run Drive, Suite 120 Westerville, OH 43082	Defendant: Ohio Builders, Inc. and Mr. David B. Holbert, President Plaintiff: Rick and Karen Upchurch (Supported Defendant)	Mold Contamination	Negotiated Settlement 01/2008	SUR-07-001	2007-2008
Mr. Thomas E. Schwartz Holloran White & Schwartz LLP 2000 S. 8th Street St. Louis, Missouri 63104	Plaintiff: Paula Dangerfield Defendant: BP Corp. North America, Inc. et al. Third Judicial Circuit Court, Madison County, State of Illinois (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 2014	SCH-07-001 Case #: 08-L-1032	2007-2014
Mr. James Billings Zacks Law Firm 33 S. James Road Columbus, OH 43213	Plaintiff: Joseph Pingue Defendant: Able Roofing Franklin County, Ohio Court of Common Pleas (Supported Plaintiff)	Roofing/Water Infiltration Testified in Trial 6/9/2008	Decision in Favor of Plaintiff	ZAC-08-001	2008
Mr. Thomas E. Schwartz Holloran White & Schwartz LLP 2000 S. 8th Street St. Louis, Missouri 63104	Plaintiff: Tricia Mary Iraci and the Estate of Giacomo Iraci Defendant(s): Heritage-Crystal Clean, LLC, Superior Solvents & Chemicals, Inc., Citgo Petroleum Corporation, Sunoco, Inc., The Valvoline Company and 3M Company Circuit Court of Cook County Illinois County Department, Law Division (Supporting Plaintiff)	Benzene Exposure Deposed by Defendant(s) 5/04/2011	-	SCH-2008-001 Case No.: 05 L 7528	2008
Mr. Thomas E. Schwartz Holloran White & Schwartz LLP 2000 S. 8th Street St. Louis, Missouri 63104	Plaintiff: Tomas Fields Defendant: The Alton & Southern Railway Company Circuit Court – St. Clair County, IL (Supported Plaintiff)	Railroad Diesel and Benzene Exposure Deposed by Defendant(s) 3/16/2010	Negotiated Settlement 8/2010	SCH-2008-003 Cause: 06L 308	2008-2010
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Elmer B. Haymond and Norma Haymond Defendant(s): Moore North American, Inc. et al. Circuit Court of Marshall County, WV (Supported Plaintiff)	Organic Chemical Exposure	Negotiated Settlement	HAR-2008-001 Cause No.: 04-C-211	2008

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff: Daniel E. Emery and Liselle Emery Defendant(s): Shell Oil Company, Individually and d/b/a Shell Chemical Company and as Successor-by-Merger to Pennzoil-Quaker State Company, a Delaware Corporation, Pennzoil-Quaker State Company, C. E Bradley Laboratories, Inc., Exxon Mobil Corporation, Safety-Kleen Systems, Inc., f/k/a Safety-Kleen Corp., The Coleman Company, Inc., Cleveland Lithochrome, Company, Inc., Minnesota Mining and Manufacturing Company (3-M), Miles Supply Company, Inc., Granite City Tool Company of Vermont, Inc., Intertape Polymer Corp. State of Vermont, Washington County, SS (Supporting Plaintiffs)	Benzene Exposure Deposed by Defendant(s) 7/21/2010	Negotiated Settlement	HAR-2008-002 Cause No. 80-2-09 WNCV	2008
Mr. Karl Novak Richardson, Patrick, Westbrook & Brickman, LLC 174 East Bay Street Charleston SC 29401	Plaintiff(s): Debra Herzog, Individually and as Administrator of the Estate of Kent Herzog, Deceased, for the use and benefit of Surviving Next of Kin, Debra Herzog (Surviving Spouse), Ryan Herzog, and Heather Ragan (Surviving Children) Defendant(s): Tex-Trim, Inc.; Sunnyside Corp.; E.I. DuPont De Nemours and Company; Superglue Corp.; The Savogran Company; RPM Wood Finishes Group; Inc., Wilsonart International, Inc., WD-40 Company, W.M. Barr & Co., Inc., DAP, Inc.; Mohawk Finishing Products, Inc.; The Glidden Co., D/B/A ICI Paints; OSI Sealants, Inc.; Do it Best Corp.; Henkel Consumer Adhesives; Inc., Henkel Corp., Individually and as successor to Henkel Locktite Corp.; Sovereign Specialty Chemicals; Henkel Consumer Adhesives, Inc., OSI Sealants, Inc., and Formica Corp.; IPS Corp. (formally Industrial Polychemical Service); Franklin International, Inc. (formerly Franklin Glue); Camie-Campbell, Inc. (formerly Camie Co.); and Camie-Campbell International, Inc. Circuit Court of the Third Judicial Circuit, Madison County, Illinois (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 02/2010	RPWB-2008-001 Cause No.: 207-L-538	2008-2010
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Walter Mairose, Individually and as Executor of the Estate of Mae I. Mairose et al. Defendant(s): The Dow Chemical Company et al. Circuit Court for Baltimore City, County of Baltimore, State of Maryland (Supported Plaintiff)	Vinyl Chloride Exposure	Negotiated Settlement 08/2008	HRCL-2008-001 Case No.: 24-C-06-011110	2008
Mr. Keith Patton Shrader & Associates	Plaintiff(s): John Davis Ward, et al. Defendant(s): Citizens Gas & Coke Utility	Benzene Exposure	Negotiated Settlement	SCHM-08-001 Cause No.:	2008

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
3900 Essex Lane, Suite 390 Houston, TX 77027	Marion County Superior Court, State of Indiana (Supported Plaintiffs)		05/2008	49D03-0701-CT-002020	
Mr. Gene Egdorf The Lanier Law Firm 6810 FM - 1960 West Houston, Texas 77069	Plaintiff(s): Judy A. Bates, individually and as Personal Representative of the Heirs and Estate of Loren G. Bates, Deceased, et al. Defendant(s): Shintech, Inc. et al. United States District Court for the Western District of Missouri (Supported Plaintiff)	Vinyl Chloride Exposure	Negotiated Settlement 2008	LAN-08-001 Cause No.: 06-0944-CV-W-GAF	2008-2008
Mr. Zach Zatezalo Bordas & Bordas, PLLC 1358 National Road Wheeling, West Virginia 26003	Plaintiff(s): Mr. Joe Berry Charlton, Vicki Charlton (wife), and Shasta Charlton (daughter) Defendant: Wheeling-Pittsburgh Steel Corp. West Virginia Worker's Compensation Office of Judges & Brooke County Circuit Court (Supported Plaintiffs)	Coke Oven Gases and Heat Exposure Deposed by Defendant 05/10/2011	Negotiated Settlement 2012	BOR-08-003 Claim #: 2006204793 Cause No.: 07-C-119	2008-2012
Mr. Andrew J. DuPont Locks Law Firm The Curtis Center 601 Walnut Street, Suite 720 East 170 South Independence Mall West Philadelphia, Pennsylvania 19106	Plaintiff(s): Michael Cardello and Tracy Cardello, his wife Defendant: CRC Industries, Inc. et al. Court of Common Pleas of Allegheny County, State of Pennsylvania (Supporting Plaintiffs)	Benzene Exposure	-	LOC-08-001 Cause No. GD-05-029307	2008
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Robert B. Oakley (Deceased) and Irene Oakley Defendant(s): Air Products and Chemicals, Inc., Aristech Chemical Corporation; Atlantic Richfield Company, BP Corporation of America, Inc., BP Products North America , Inc., BP Amoco Chemical Company, Occidental Chemical Corporation, Radiator Specialty Company, United States Steel Corporation, and USX Corporation U.S. District Court for the Eastern District of Texas Marshall Division (Supported Plaintiff)	Benzene Exposure 11/25/2008 - Defendant(s) motion to exclude Petty testimony denied.	Negotiated Settlement 12/2008	HRCL-08-002 Case No.: 2:07-CV-00351	2008
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Gerald Diaz (deceased) and Deborah Diaz Defendant(s): Handschy Industries, Inc., E.I. DuPont de Nemours & Co., et al. In the District Court, Orange County, 128th Judicial District Court (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 8/2012	HRCL-08-003 Cause No.: A-070037DC	2008-2012
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building	Plaintiff(s): Mr. Richard Gordon Defendant(s): Texaco Marine Services, Inc. et al.	Benzene Exposure	Negotiated Settlement 08/2011	HAR-08-005	2008-2011

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
2001 Main Street, Suite 600 Wheeling, WV 26003	United States District Court for the District of New Jersey (Supported Plaintiff)	Deposed by Defendant(s) 6/28/2011		Cause No. 09 CV-911 (JAG)	
Mr. Keith Patton Shrader & Associates 3900 Essex Lane, Suite 390 Houston, TX 77027	Plaintiff(s): Mr. Raul Zendejas and Araceli Zendejas. Defendant(s): Shell Oil Company, Shell Chemical, LP, Individually and as Successor-in-interest to Shell Chemical Corporation, ConocoPhillips Company, Von Verde Citrus Packing House, Inc., an Arizona corporation; Von Verde Harvesting, Inc., a dissolved Arizona corporation; and Von Verde Citrus Growers Cooperative, Inc a dissolved Arizona Corporation In the Superior Court of the State of Arizona in and for the County of Maricopa (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant(s) 9/23/2009 Trial Testimony 11/9-10/2009	Decision in Favor of Defendant(s) 11/19/2009	SCHM-08-002 Cause No.: CV-2007-005399	2008-2009
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Bonnie L. Mallory, Executrix of the Estate of Robert E. Mallory, Deceased Defendant(s): Goodyear Tire & Rubber Company, Akron, OH, et al. Court of Common Pleas, Summit County, Ohio (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 10/21/2009	Negotiated Settlement 2010	HAR-08-006 2007-11-8033 Case No.: CV07-11-8033	2008-2010
Mr. Raphael Metzger Metzger Law Group 401 E. Ocean Blvd., Suite 800 Long Beach, CA 90802	Plaintiff(s): Thomas Wayne Reese Defendant: Gans Ink & Supply Co., and Does 1 through 200, inclusive Superior Court of the State of California for the County of Los Angeles – Central District (Supported Plaintiff)	Benzene Exposure Deposed by Defendant 7/7/2009	Negotiated Settlement 05/2010	MET-08-001 Case No.: BC332936	2008-2010
Mr. Guy Bucci Bucci, Bailey & Javins 213 Hale Street Charleston, WV 25301	Plaintiff(s): Michael Schmidt Defendant: Bayer Corporation, Bayer Material Science LLC, John Cool, Terry Eddy, Charles "Buddy" Kotson and John Long Circuit Court of Marshall County, West Virginia 7/28/2008 2nd Amended Complaint Filed (Supported Plaintiff)	TDI Exposure Deposed by Defendant 02/03/2010 and 06/03/2010	Negotiated Settlement 09/2012	BUC-07-001 Case No.: 08-C-121-K	2007-2012
Mr. Thomas E. Schwartz Holloran White & Schwartz LLP 2000 S. 8th Street St. Louis, Missouri 63104	Plaintiff(s): Suzanne Schaefer, Individually and as Special Administrator of the Estate of Richard D. Schaefer, Deceased Defendant: The Premcor Refining Group, Inc. formerly known as Clark Refining & Marketing, Inc. and formerly known as Clark Oil & Refining Corporation, and Illinois Petroleum Company, Inc. and Texor Petroleum Company,	Benzene Exposure	-	SCH-08-005 Case No.: 06 L 578	2008

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Inc., and Parent Petroleum, Inc. Circuit Court of Will County, State of Illinois (Supporting Plaintiff)				
Ms. Kelly McMeekin Paul & Hanley 1608 Fourth Street, Suite 300 Berkeley, CA 94710	Plaintiff(s): Julie (Judy) Murray, Individually and as Successor-In-Interest to Erica Murray Defendant: Chevron Corporation; Union Oil Company of California; Greka Oil & Gas, Inc.; Drilling & Production Co.; ConocoPhillips, Kerr-McGee Corporation; Anadarko Petroleum Corporation, Key Energy Group, Inc. and DOES 2-210 Superior Court of the State of California, County of Los Angeles (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 10/28-29/2009	Closed 2010	PAU-08-001 Case No.: YCO56221	2008-2010
Mr. Michael P. Giertz **Hartley & O'Brien**, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Douglas E. Fedor Defendant: Norfolk Southern Railway Co. (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 11/2008	HAR-08-007 Case No.: CV-08-652069	2008
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Candis L. Snyder, individually, and as the Personal Representative of the Estate of William Luther Clark, Deceased; Patricia L. Clark, Shelley K. Winfrey and Kerry A. Clark, Individually and as the Wrongful Death Beneficiaries of the Estate of William Luther Clark, Deceased Defendant: E.I. DuPont De Nemours and Company, Inc., PPG Industries, Inc., Sherwin Williams Company, BASF Corp., Wesco Group, Inc. U.S. Steel/Aristech Chemical Corp., Radiator Specialty Company, Sunoco, Inc., The Glidden Company and ICI Americas, Inc. Superior Court of the State of Washington in and for the County of King (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 7/2010	HRCL-08-004 Case No.: 07-2-27647-5SEA	2008
Mr. R. Dean Hartley **Hartley & O'Brien**, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Christopher R. Scearce and Angela W. Scearce, his wife Defendant(s): The Sherwin-Williams Company; Abercrombie Oil Company, Inc.; Hutchens Petroleum Corporation; UNIVAR USA, Inc.; Caswell Auto Parts, LLC; Texaco, Inc.; Chemtek, Incorporated, Travelers Insurance Company and Key Risk Management Services. North Carolina Industrial Commission, Raleigh, North Carolina; State of North Carolina In the General Court of Justice Superior Court, Division, Caswell County (Supporting Plaintiff)	Benzene Exposure Deposed by Defense 10/28/2010 Testified before the North Carolina Industrial Commission 8/11/10	Negotiated Settlement	HAR-08-004 Cause No.: 08-CVS-420	2008

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Keith Patton Shrader & Associates 3900 Essex Lane, Suite 390 Houston, TX 77027	Plaintiff(s): George Oliver Tanner, Individually and as Independent Administrator of the Estate of Jimmie Wayne Tanner, Deceased Defendant: ExxonMobil Corporation et al. In the United States District Court for the Southern District of Texas Houston Division (Supporting Plaintiff)	Benzene Exposure	-	SHR-09-001 Cause No.: 01-16849-001	2009
Mr. Guy Bucci Bucci, Bailey & Javins 213 Hale Street Charleston, WV 25301	Plaintiff(s): Ricky J. Carman Defendant: Bayer Corporation, Bayer Material Science LLC, John Cool, Terry Eddy, Charles "Buddy" Kotson and John Long Circuit Court of Marshall County, West Virginia (Supported Plaintiff)	TDI Exposure Deposed by Defendant(s) 02/03/2010	Negotiated Settlement 08/2010	BUC-09-001 Case No.: 08-C-269K	2009-2010
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiff(s): Michael Malcontento Defendant: Court of Common Pleas, Philadelphia County, November Term, 2006, No: 0632 (Supported Plaintiff)	Asbestos Exposure	Negotiated Settlement 2010	BAR-009-002 Case No.: 26035 Asbestos	2009-2010
Mr. Keith Patton Shrader & Associates 3900 Essex Lane, Suite 390 Houston, TX 77027	Plaintiff(s): Ms. Barbara Way and Estate of Mr. James Way Defendant: Ashland, Inc., Exxon Mobil Corporation, Shell Oil Company, Chevron U.S.A., Inc., Goodrich Corporation, and Parker Hannifan Corporation In the Court of Common Pleas, Cuyahoga County, Ohio (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 2010	SHR-09-002 Cause No.: CV 09 683084	2009-2010
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Lewis E. Knapper and Linda Knapper Defendant: Safety-Kleen Systems, Inc., Aristech Chemical Corp., Radiator Specialty Company, Sunoco, Inc. (R&M), United States Steel Corporation, and USX Corporation. U.S. District Court for the Eastern District of Texas Lufkin Division (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant 07/16/2009 11/16/2009 - Defendant(s) motion to exclude Petty testimony denied.	Negotiated Settlement 02/2010	HRCL-09-001 Civil Action No: 9:08-cv-0084	2009-2010
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Linda Denise Smith and Estate of Wesley Fred Smith, Deceased et al. Defendant: E.I DuPont De Nemours and Company, Inc., PPG Industries Inc., Sherwin Williams Company, BASF Corporation, Akzo Nobel Coatings, Inc. United States District Court for the Eastern District of Texas,	Benzene Exposure	Negotiated Settlement 6/2010	HRCL-09-002 Cause No.: 08-CV-385	2009-2010

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Beaumont Division (Supported Plaintiff)				
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Fred Cantu and Ruth Cantu Defendant: BP Amoco Chemical Company et al. In the District Court of Galveston Texas, 56th Judicial District (Supported Plaintiffs)	Benzene Exposure	Dismissed 2010	HRCL-09-003 Cause No.: 07 CV 0594	2009-2010
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Darla J. Lemaire, Individually, and as the Independent Executrix of the Estate of Michael Lemaire, Deceased et al. Defendant: Berryman Products, Inc.; Delaware USS Corporation, Huntsman Petrochemical Corporation, Radiator Specialty Company, Texaco Chemical Company, Texaco, Inc., United States Steel Corporation, and USX Corporation 172nd Judicial District of Jefferson County, Texas (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 10/13/2009	Negotiated Settlement 10/31/2009	HRCL-09-007 Cause No.: E-178,440	2009
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): Ryan Glenn Davis and Evan Scott H. Davis, Executors of the Last Will and Testament of Ronald Davis, Deceased. Defendant(s): Sunoco, Inc. (R&M) f/k/a Sun Company, Inc., Radiator Specialty Company, United States Steel Corp., Insilco Technologies, Inc., Eastman Kodak Co., The Sherwin-Williams Co., et al. Court of Common Pleas, Philadelphia County (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 2011	LOC-2009-002 Cause No.: 090301835	2009-2011
Mr. Andrew DuPont Locks Law Firm The Curtis Center 601 Walnut Street, Suite 720 East Philadelphia, Pennsylvania 19106	Plaintiff(s): Richard Ascani Defendant: E.I. Du Pont Nemours & Company, BASF Corp, SM Co., Safety-Kleen Systems, Inc., et al. Supreme Court of the State of New York, County of Kings (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 2010	LOC-09-003 Cause No.: 12061-09	2009-2010
Mr. Andrew DuPont Locks Law Firm The Curtis Center 601 Walnut Street, Suite 720 East Philadelphia, Pennsylvania 19106	Plaintiff(s): Joann Grandpre, Individually and as the Administratrix of the Estate of Anthony Grandpre, Deceased; Treva Cadres, Trina Kohlman and Troylise Grandpre, Individually and as the Beneficiaries of the Estate of Anthony Grandpre, Deceased Defendant: PPG Industries, Inc., PPG Industries Ohio, Inc., PPG Coatings, Inc., E.I. DuPont de Nemours & Co., DuPont Performance Coatings, Inc. Individually and as Successor-In-Interest to Spies Hecker, Inc., DuPont Automotive Products, Inc., Spies Hecker, Inc., BASF Corporation, BASF Coatings AG, Individually and Successor-In-Interest to Inmont Corporation, BASF-Inmont Corporation, BASF Corporation-	Benzene Exposure	Negotiated Settlement 2010	LOC-09-004 Cause No. 2004-4180, Division J, Section 13	2009-2010

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Inmont Division, The Sherwin-Williams Company, Inc., Sherwin-Williams Automotive Finishes Corp., Illinois Tool Works, Inc. Individually and Successor-In-Interest to Fibre Glass-Evercoat Company, Inc., Crescent City Color, Tarride Color Service, Inc., Tarride Sale, Inc., Automotive Paint & Trimming Supply Company, Inc., Linda's Hip Hop Auto Paint & Supply Shop, LLC. Civil District Court for the Parish of New Orleans, State of Louisiana (Supported Plaintiff)				
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiff(s): Dolores Juliano, as Executrix of the Estate of John Juliano Defendant: A.W. Chesterton Company, et al. In the Court of Common Pleas Philadelphia County, PA. (Supported Plaintiff)	Asbestos Exposure	Negotiated Settlement 2012	BAR-09-003 Cause No.: 001905	2009-2012
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiff(s): Leroy Thompson Defendant: A.W. Chesterton Company, et al. In the Court of Common Pleas Philadelphia County, PA. (Supported Plaintiff)	Asbestos Exposure	Negotiated Settlement 2009	BAR-09-004	2009
Mr. Robert Black Heard, Robins, Cloud & Lubel, LLP 3800 Buffalo Speedway, 5th Floor Houston, Texas 77098	Plaintiff(s): Susan Stevenson, Jordan W. Stevenson and Amy S. Fontenot, Individually, and as Heirs to the Estate of James Edward Stevenson Defendant: Bayer Corporation, Successor in Interest to Miles, Inc., Denka Chemical, Mobay Corporation and Mobay Chemical Company; Atofina Petrochemicals, Inc. individually and formerly known as American Petrofina Company of Texas and Fina Oil and Chemical Company; Chevron Chemical Company; Chevron U.S.A. Incorporated, individually and as successor in interest to Gulf Oil Corporation; Chevron Phillips Chemical Company, LLC; Chevron Phillips Chemical Company LP; Conoco, Inc., individually a/k/a Conoco Gas and Marketing, a Division of Conoco, Inc., and formerly known as Du Pont holdings, Inc.; ConocoPhillips Company; E.I. DuPont de Nemours and Company, Inc.; ExxonMobil Oil Corporation, individually, f/k/a Mobil Oil Corporation, and a/k/a Mobil Chemical Company, a Division of ExxonMobil Oil Corporation; Fina Oil and Chemicals; Fina, Inc.; Goodyear Tire & Rubber Company; Great Lakes Carbon Corporation; Mobil Chemical Company, Inc., individually and f/k/a Mobil Chemical Corporation; Radiator Specialty Company; United States Steel Corporation, individually, f/k/a United States Steel LLC, and	Benzene Exposure	Negotiated Settlement 02/2010	HRCL-09-008 Case No.: A-040211-C	2009

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	f/k/a USX Corporation; and USX Corporation, individually, f/k/a U.S. Steel Company, f/k/a United States Steel Corporation and as a subsidiary of Marathon Oil Company 128th Judicial District Court, Orange County, Texas (Supported Plaintiffs)				
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiff(s): Stephen J. Kolar and Carol Kolar Defendant: Buffalo Pumps, Inc. et al. Philadelphia County Court of Common Pleas Civil Trial Division (Supported Plaintiffs)	Asbestos Exposure	Negotiated Settlement 2010	BAR-09-005 Case No.: 000199 Asbestos	2009-2010
Ms. Denyse Clancy Baron & Budd, P.C. 3102 Oak Lawn Ave., Suite 1100 Dallas, TX 75219	Plaintiff(s): Earl J. Goodhart and Betty R. Goodhart h/w Defendant: Garlock Sealing Technologies, et al. In the Court of Common Pleas Philadelphia County, PA (Supported Plaintiffs)	Asbestos Exposure	Negotiated Settlement 03/2010	BAR-2009-006 Case No.: 0000436 Asbestos	2009-2010
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): John M. Ashworth and Johnnie M. Hord, Individually and Executrix of the Estate of Anthony T. Hord, deceased Defendant(s): The Goodyear Tire & Rubber Company et al. Court of Common Pleas, Summit County, Ohio (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement May 2010	HAR-09-001 Case No.: 2008-10-7361	2009-2010
Mr. R. Dean Hartley Hartley & O'Brien, P.L.L.C. The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s)s: Johnnie M. Hord, Individually and Executrix of the Estate of Anthony T. Hord, deceased and John M. Hord Defendant(s): The Goodyear Tire & Rubber Company et al. Court of Common Pleas, Summit County, Ohio (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 07/07/2010	Negotiated Settlement 12/2010	HAR-09-001 Case No.: 2008-10-7361	2009-2010
Mr. Ted Gianaris Simmons Attorneys At Law 707 Berkshire Blvd. P.O. Box 521 East Alton, IL 62024	Plaintiff(s)s: Tristan Tolloty, a minor, by his next friends and parents, Brian Tolloty and Jessica Tolloty Defendant(s): Republic Services, Inc. Republic Services of Ohio, II, LLC, Waste Management, Inc., and Waste Management of Ohio, Inc. In the Court of Common Please, Stark County, Ohio (Supported Plaintiffs)	Benzene Exposure	Resolved 7/2012	SIM-09-001 Case No.: BC 416990	2009-2012
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): Kenneth Roberts and Helen Jean Roberts, his wife. Defendant: Sunoco, Inc. (R&M) f/k/a Sun Company, Inc. and f/k/a Sun Oil Company, Inc., etc. Court of Common Pleas, Philadelphia County	Benzene Exposure	Negotiated Settlement 3/2012	LOC-09-005 Case No.: 3320	2009-2012

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	(Supported Plaintiffs)				
Mr. Greg Lofstead Richardson, Patrick, Westbrook & Brickman, LLC 1017 Chuck Dawley Blvd. Mt. Pleasant, SC 29464 & Mr. Timothy C. Bailey Bucci Bailey & Javins LC PO Box 3712 Charleston, WV 25337	Plaintiff(s): Clarence J. Dorsey and Susan Dorsey Defendant: Copperas Coal Corporation; Hunter Ridge Coal Company, f/k/a Anker Energy Corporation; Brooks Run Mining Company, LLC; Fossil Fuels, Inc.; and Kingston Mining, Inc. Circuit Court of Nicholas County, West Virginia (Supported Plaintiffs)	Silica Dust Exposure Deposed by Defendant(s) 09/10/2010	Negotiated Settlement 9/10/2010	RPWB-10-001 Case No.: 09-C-36	2010-2010
Mr. Raphael Metzger Metzger Law Group 401 E. Ocean Blvd., Suite 800 Long Beach, CA 90802	Plaintiff(s): Laura Hammond, individually and as Guardian ad Litem of Minors Rachel Hammond and John Hammond; Craig Hammond; Elizabeth Wust; Marissa Stockreef; Stephanie Head, and Geoffrey Head Defendant: Chevron Corporation; Chevron USA, Inc.; Angeles Chemical Co., Inc.; Ashland Inc.; Ashland Oil, Inc.; Bortz Oil Co., Inc.; Chemcentral Corp; The Dow Chemical Company; E.I. Du Pont de Nemours and Company; Shell Oil Company; SOCO West Inc.: Union Carbide Corporation and Univar USA Inc. Superior Court of the State of California for the County of Los Angeles – Central District (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant(s) 5/27/2010 Testified in Trial 01/26/2011	Decision in Favor of Defendant 2/2011	MET-10-001 Case No.: BC 358265	2010-2011
Mr. Robert Black Heard Robins Cloud & Black 9 Greenway Plaza, Suite 2300 Houston, Texas 77046	Plaintiff(s): Patricia A. McClurg, Individually and as the Representative of the Estate of Duard Wayne McClurg, Deceased and Terena McClurg Defendant(s): Ingram Barge Company, Savogran Company, W.M. Barr Company, Inc., et al. United States District Court, Eastern District of Texas, Beaumont Division (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 11/2010	HRCB-10-002 Case No.: 1:09-CV-00504	2010
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): John J. Mull, III, and Renee Crimmins, H/W Defendant: The Sherwin Williams Company; M.A. Bruder & Sons, Inc.; Urbanik Paint & Wallpaper Co., Inc.; Tnemec, Inc.; Benjamin Moore & Co. Duron Paints & Wallcoverings; Texaco, Inc.; ChevronTexaco Corp.; Getty Petroleum Marketing, Inc. f/k/a Getty Realty Corp. f/k/a Power Test Corp.; Lukoil Americas Corp; Mikecon Corp.; Exxon Mobil Corp; Getty Realty Corp. and John Doe Corporations One through Ten (1-10) Superior Court of New Jersey, Law Division – Camden	Benzene Exposure Deposed by Defendant(s) 03/17/2011	Negotiated Settlement 5/17/2011	LOC-10-001 Case No.: CAM-L-884-07	2010-2011

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	County (Supported Plaintiffs)				
Mr. Keith Patton Shrader & Associates, L.L.P. 3900 Essex Lane, Suite 390 Houston, TX 77027	Plaintiff(s): Sharon Claytor, Personal Representative of the Estate of Rick D. Lewis; and Hilarie Lewis, Heir of Rick D. Lewis Defendant: Rebel Oil Company, a Nevada Corporation; Kinder Morgan Energy Partners, L.P.; ConocoPhillips Company; Shell Chemical Company; Chevron U.S.A., Inc.; Tosco Corporation; Tosco Refining Company; BP Products North America, Inc. and Atlantic Richfield Company District Court, Clark County, Nevada (Supported Plaintiffs)	Benzene Exposure	Testified in Trial 09/27-28/2011 Decision in Favor of Plaintiff 10/2011 Decision Confirmed by the Supreme Court of Nevada 12/16/2014	SHR-10-001 Case No.: A566869, Dept. XVII	2010-2011
Mr. Darren Brown Provost Umphrey Law Firm, LLP 490 Park Street Beaumont, Texas 77701	Plaintiff(s): Monte McWilliams Defendant(s): Exxon Mobil Corporation et al. 14th Judicial District Court, Parish of Calcasieu, State of Louisiana, Division E (Supported Plaintiff)	Benzene Exposure	Decision in Favor of Plaintiff 02/2012	PRO-10-001 Cause No.: 2009-002803	2010-2012
Mr. Keith Patton Shrader & Associates, L.L.P. 3900 Essex Lane, Suite 390 Houston, TX 77027	Plaintiff(s): Richard Czuprynski Defendant: The Kansas City & Southern Railway Company Circuit Court of Jackson County, Missouri (Supporting Plaintiff)	Benzene from Benzene-Containing Products Deposed by Defendant 11/29/2011	Dismissed	SHR-11-001 Cause No.: 1016-CV06186, Division No. 4	2011-2012
Mr. Greg Coolidge Metzger Law Group 401 E. Ocean Blvd., Ste. 800 Long Beach, CA 90802	Plaintiff(s): Steven Billing et al. Defendant(s): Azko Nobel Paints, LLC et al. Superior Court of the State of California for the County of Los Angeles (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 01/2012	MET-11-001 Case No.: BC 416990	2011-2012
Mr. Brian Madden Wagstaff & Cartmell, LLP 4740 Grand Avenue, Suite 300 Kansas City, MO 64112	Plaintiff(s): Charles Ross and Rocio Ross Defendant(s): Chevron Phillips Chemical Company, LP; Chevron Phillips Chemical Holdings II, LLC; and Chevron Phillips Chemical Company, LLC. District Court of Montgomery County, Texas, 284th Judicial District (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant(s) 04/24/2012	Negotiated Settlement 03/2012	WAG-11-001 Case No.: 10-02-01901-CO	2011-2012

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Keith Hyde Provost Humphrey P.O. Box 4905 Beaumont, Texas 77704	Plaintiff(s): Jo Beth Allen and Lisa Wolfe, Surviving Children of Joe Allen, Deceased Defendant(s): Texaco, Inc., Chevron USA, Inc. and Atlantic Richfield Company In the District Court, Jefferson County, Texas, 60th Judicial District (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 03/2012	PRO-11-001 Cause No. B-186,652	2011-2012
Ms. Jo Anna Pollock Simmons Attorneys At Law 707 Berkshire Blvd. P.O. Box 521 East Alton, IL 62024	Plaintiff(s): City of Roxana Defendant(s): Shell Oil Company, Equilon Enterprisers, LLC d/b/a Shell Oil Products, US, a Corporation, ConocoPhillips Company, WRB Refining LP, ConocoPhillips WRB Partner, LLC, and Cenovus GPCP, LLC. The Circuit Court Third Judicial Circuit Madison County, IL (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant(s) 11/05/2015	Negotiated Settlement 2016	SIM-11-001 Case No.: 3:12-cv-00336 GDM-PMF	2011-2016
Mr. Brad Oldaker Bailey, Stultz, Oldaker & Greene 122 Court Avenue Weston, WV 26452	Plaintiff(s): Ralph E. Taylor, Kathy Taylor, individually and in their capacity as guardian and next friend of Jane Doe, a minor. Defendant(s): E.I. Du Pont & Company, a Delaware Corporation, KBR, Inc., a Delaware Corporation, BE&K Construction Company, L.L.C., a Delaware Corporation and Debra Hartman, an Individual. In the Circuit Court of Kanawha County, West Virginia. (Supported Plaintiff)	Safety (Scaffold Incident)	Negotiated Settlement 09/2012	OLD-11-001 Case No. 11-C-1713	2011-2012
R. Dean Hartley Hartley & O'Brien, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Cynthia L. Gunto, Individually and as Executrix of the Estate of Michael T. Gunto, deceased. Defendant(s): PPG Industries, Inc. Circuit Court of Marshall County, West Virginia (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 03/2013	HAR-11-001 Case No.: 09 C 260K	2011-2013
Mr. Gary L. Hall Smith, Rolfes & Skavdahl Co., LPA 600 Vine Street, Suite 2600 Cincinnati, OH 45202	Plaintiff(s): Rex A. Absher and Cosetta Absher Defendant(s): State Auto Insurance Company of Ohio In the Court of Common Pleas Lawrence County, Ohio. (Supported Insurance Company - Defendant)	Formaldehyde Exposure Deposed by Plaintiffs 02/09/2012	Decision in Favor of Plaintiff	STE-12-001 Case No.: 10-OC-908	2011-2012
Dr. Herschel L. Hobson Hobson & Bradley Attorneys At Law 2190 Harrison Beaumont, TX 77701	Plaintiff(s): William P. Hite and Patricia A. Hite Defendant(s): Apex Oil Company, Inc., Valero Energy Corp., successor in interest to Clark Oil Company and Premcor, Inc. et al. Circuit Court of Cook County Illinois, County Department, Law Division	Benzene Exposure Deposed by Defendant(s) 04/02/2013	Negotiated Settlement 2/2014	HOB-11-001 Case No.: 09 L 4510	2011-2014

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	(Supported Plaintiff)				
Mr. Ted Gianaris Simmons Attorneys At Law 707 Berkshire Blvd. P.O. Box 521 East Alton, IL 62024	Plaintiff(s): James and Betty Cox Defendant(s): Shell Oil Company, Equilon Enterprisers, LLC d/b/a Shell Oil Products, US, a Corporation, ConocoPhillips Company, WRB Refining LP, ConocoPhillips WRB Partner, LLC, and Cenovus GPCP, LLC. (Supported Plaintiffs)	VOC Exposure Site Visit, Interview and Report	Resolved Pre-Litigation 2014	SIM-12-001	2012-2014
Mr. Keith Hyde Provost Humphrey P.O. Box 4905 Beaumont, Texas 77704	Plaintiff(s): Claude W. Shute & Arthur Earl Holmes Defendant(s): Citgo Petroleum Company; Canadianoxy Offshore Production Co., ConocoPhillips Company; ExxonMobil Corporation; Chevron U.S.A., Inc.; Texaco, Inc.; Fina, Inc.; GATX Corporation; Crown Petroleum Corporation; Shell Oil Company; Hartford Accident & Indemnity Company; Century Indemnity Company and Lloyds of London In the 14th Judicial District Court of Calcasieu Parish, Louisiana (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 09/2012	PRO-12-001 Cause No.: 2010-003436 "E"	2012
Mr. Andrew DuPont Locks Law Firm The Curtis Center 601 Walnut Street, Suite 720 East 170 South Independence Mall West Philadelphia, Pennsylvania 19106	Plaintiff(s): Sondra Krem, Individually and as Executrix of the Estate of Joseph J. Krem Defendant(s): BP Corporation North America, Inc., Atlantic Richfield Company, Sunoco, Inc. (R&M) f/k/a Sun Company, Inc., Radiator Specialty Company, United States Steel Corporation, Safety-Kleen Systems d/b/a Safety-Kleen, Safety-Kleen Corp. in its own right and d/b/a Safety-Kleen Systems, Inc., The Pep Boys-Manny, Moe & Jack, The Berkebile Oil Company, Inc. and CRC Industries, Inc. In the Court of Common Pleas of Philadelphia County, Pennsylvania – Civil Division (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 11/2012	LOC-12-001 Case No.: 01913	2012
Mr. Andrew J. Stern Kline & Specter 1525 Locust Street Philadelphia, PA 19102	Plaintiff(s): Ruben Grigoryants and Mariana Grigoryants Defendant(s): Safety-Kleen Systems d/b/a Safety-Kleen, Safety-Kleen Corp. in its own right and d/b/a Safety-Kleen Systems, Inc. In the United States District Court for the Western District of Pennsylvania (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 04/2016	KLI-12-001 Case No.: 1:11-cv-00267-SJM	2012-2016
Mr. Andrew DuPont Locks Law Firm The Curtis Center 601 Walnut Street, Suite 720 East 170 South Independence Mall West	Plaintiff(s): David Gerchman and Teresa Gerchman Defendant(s): Berryman Products, Inc.; CRC Industries, Inc., Ford Motor Company, Loctite Corporation n/k/a Henkel Corporation; Illinois Tool Works, Inc., solely as successor-in-interest to Permatex, Inc.; Radiator Specialty Company;	Benzene Exposure Deposed by Defendant(s) on July 16, 2012.	Negotiated Settlement 08/2012	LOC-12-002 Case No. VC060106	2012-2012

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Philadelphia, Pennsylvania 19106	United States Steel Corporation, Safety-Kleen Corp., Safety-Kleen Systems, Inc., 3M Company; E.I. DuPont de Nemours & Company; Sea Foam Sales Company; Justice Brothers, Inc.; Hanson Merrill Corporation a/k/a Ernie's Auto Parts and Henkel Corporation In the Superior Court of the State of California for the County of Los Angeles, Southeast District (Supported Plaintiffs)				
Mr. Thomas E. Schwartz Holloran White & Schwartz LLP 2000 S. 8th Street St. Louis, Missouri 63104	Plaintiff(s): Jeannette Platt, as the surviving wife of Decedent Lawrence Platt, Lukas Platt and Zachary Platt, as the surviving children of Decedent, Loretta Platt, as the surviving mother of Decedent, and Francis Platt, John Platt and Edward Platt, as the surviving siblings of Decedent Defendant(s): BASF Corporation, D&A Distributing, Inc., E.I. DuPont de Nemours & Company, Link Motor Supply Company, Inc., PPG Industries, Inc., and the Sherwin Williams Company In the Circuit Court of St. Louis County, State of Missouri (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 02/2013	SCH-12-001 Case No.: 10SL-CC01305	2012-2013
Mr. Keith Hyde Provost Humphrey P.O. Box 4905 Beaumont, Texas 77704	Plaintiff(s): Billy Smallwood & George C. Washington Defendant(s): Exxon Mobil Corporation et al. In the 136th Judicial District Court of Jefferson County, Texas (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant(s) on October 17, 2013	Negotiated Settlement 11/2013	PRO-12-002 Case No.: D-189,648	2012-2013
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): Andre A. Harvey Defendant(s): Valero Energy Corporation, PBF Energy Company, LLC, Paulsboro Refining Company, LLC, Sunoco, Inc. (R&M) a/k/a Sun Oil Company, Inc. and Sun Company, Inc., Sunoco Logistics Partners, L.P., El Paso Corporation, The Carlyle Group, L.P., Delaware City Refining Company, LLC, Husky Energy, Inc., Lima Refining Company In the Court of Common Pleas of Philadelphia County (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 01/20/2017	LOC-12-003 Case No. 121102430; 02471	2012-2017
Mr. Brian E. Fritz Saltz, Mongeluzzi, Barrett & Bendesky, P.C. One Liberty Place, 52nd Floor Philadelphia, PA 19103	Plaintiff(s): Jeanne Gans, Administratrix of the Estate of George Gans, and in her own right Defendant(s): Sunoco, Inc., and Sunoco (R&M) Inc. Philadelphia County Court of Common Pleas Law Division (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 3/2014	SMBB-13-001 Case No.: 03399	2013-2014
Mr. Guy R. Bucci Bucci Bailey & Javins LC PO Box 3712	Plaintiff(s): William (Rick) Potter Defendant(s): B&F Contracting, Inc. and its successors 198	Fall Protection	Negotiated Settlement 5-2015	BUC-13-002	2013-2015

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Charleston, WV 25337 Mr. Chris Heavens Heavens Law Firm PLLC 2438 Kanawha Blvd., East Charleston, WV 25311	State Road 716, Ashland KY 41102 (Supported Plaintiff)	Pre-Suit – Wrote Expert Report			
Mr. Guy R. Bucci Bucci Law Firm PO Box 3712 Charleston, WV 25337	Plaintiff(s): Muriel A. Thomas and Jackie Thomas, her husband Defendant(s): Interiors Plus, LLC, a West Virginia Limited Liability Company, CENTAUR Floor Systems, LLC, ECORE International, Inc. a Pennsylvania Corporation, and Russell Morrison d/b/a/ Alpha Professional, vs. Bostic, Inc., Third-Party Defendant In the Circuit Court of Kanawha County, West Virginia (Supported Plaintiffs)	Exposure to MDI	WV Workers' Compensation Office of Judges Decision of Reversal in Favor of Plaintiffs 12/19/2014 Negotiated Settlement 05/2016	BUC-13-001 Case No.: 14-C-106	2013-2016
Mr. Brian E. Fritz Saltz, Mongeluzzi, Barrett & Bendesky, P.C. One Liberty Place, 52nd Floor Philadelphia, PA 19103	Plaintiff(s): John and Jacquelyn Coen, Husband and Wife Defendant(s): Carboline Co., RPM, et al. Philadelphia County Court of Common Pleas Law Division (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 11/2013	SMBB-13-002 Case No.: 1714	2013
Ms. Jo Anna Pollock Simmons Attorneys At Law 707 Berkshire Blvd. P.O. Box 521 East Alton, IL 62024	Plaintiff(s): Bridgeton Class Action – Marsha Buck, Troy Lewis, Jean Lewis, Mike Head and Janet Head, individually and on behalf of all others similarly situated. Defendant(s): Republic Services, Inc., Allied Services LLC d/b/a Republic Services of Bridgeton, Bridgeton Landfill, LLC In the United States District Court Eastern District of Missouri. (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant(s) 10/30/2013	Negotiated Settlement 2013	SIM-13-002 Case No.: 13-CV-00801	2013
Mr. Douglas J. May Travelers Staff Counsel 625 Eden Parkway, Suite 510 Cincinnati, OH 45202	Plaintiff(s): Arshot Investment Corporation, et al. Defendant(s): E.V. Bishoff Company, et al. In the Court of Common Pleas Franklin County, OH (Supported Defendant – Mason)	Brick Veneer Failure Structural at Hampton Inn, Columbus, OH Site visit and Expert Report	Negotiated Settlement 2/2014	TRA-13-001 Case No.: 12CV-10-12920	2013-2014
Mr. John Vincent Weston Hurd LLP 10 W. Broad St., Suite 400 Columbus, OH 43215	Plaintiff(s): Tutor Time 123 LLC Defendant(s): Air Force One, Inc. Pre-Lawsuit (Supporting Defendant)	HVAC Failure Claimed Site Visit and Expert Report	Settled 2013	WES-13-001 Claim #: NR-CMM-6050718-110913-A	2013

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): David A. Johnson and Laura Johnson Defendant(s): Armored Autogroup, Inc. d/b/a STP; Berryman Products, Inc.; CRC Industries, Inc., Loctite Corporation n/k/a Henkel Corporation; Illinois Tool Works, Inc., solely as successor-in-interest to Permatex, Inc.; Radiator Specialty Company; United States Steel Corporation, Safety-Kleen Corp., Safety-Kleen Systems, Inc., 3M Company; Texaco, Inc.; Chevron U.S.A., Inc., Individually and Successor in Interest to Texaco, Inc., Justice Brothers, Inc.; Genuine Parts Company; Henkel Corporation Individually and as Successor in Interest to Loctite Corporation and Henkel Loctite Corporation; Sunoco, Inc. (R&M); Volvo Cars, etc. In the Superior Court of the State of California for the County of Alameda (Supported Plaintiffs)	Benzene Exposure Deposed by Defendant(s) 3/21/2014; 4/8/2014; 4/24/2014	Negotiated Settlement 6/2014 Re-opened 2016 and re-settled 9/2016	LOC-13-001 Case No.: 001641 A142485 In the Court of Appeal of the State of California, First Appellate District	2013-2016
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): David Butler and Teri Rhodes Defendant(s): Sunoco, Inc. (R&M) FKA Sun Company, Inc. FKA Sun Oil Company; United States Steel Company; and Radiator Specialty Company. In the Court of Common Pleas of Philadelphia County, Pennsylvania Civil Division (Supported Plaintiffs)	Benzene Exposure	Testified in Trial 7/29-30/2014 Decision in Favor of Defense 8/8/2014	LOC-13-001 Case No.: 001641	2013-2014
Mr. Thomas E. Schwartz Holloran White & Schwartz, LLP 2000 South 8th Street St. Louis, MO 63104	Plaintiff(s): Elroy Buyat, Jr. Defendant(s): Mallinckrodt, Inc., Covidien, Inc., Safety-Kleen Systems, Inc., Heritage-Crystal Clean, LLC., and Engineered Lubricants, Co In the Circuit Court of St. Louis County, State of Missouri (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 2014	HOL-13-001 Case No.: 1122-CC00786	2013-2014
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): Layne Kleinschmit and Cynthia Kleinschmit Defendant(s): 3M Company; Berryman Products, Inc.; The Blaster Corporation, CRC Industries, Inc., Genuine Parts Company, d/b/a NAPA; Henkel Corporation, individually and as successor in interest to Loctite Corporation and Henkel Locktite Corporation; Loctite Corporation n/k/a Henkel Corporation; Illinois Tool Works, Inc., d/b/a Permatex and d/b/a Gumout and d/b/a LPS Laboratories and d/b/a Wynn's.; The Pep Boys – Manny, Moe & Jack; Radiator Specialty Company; Safety-Kleen Corporation, Safety-Kleen Systems, Inc., Sunoco, Inc. (R&M) f/k/a Sun Company, Inc. and f/k/a Sun Oil Company, Inc., Technical Chemical Company; and	Benzene Exposure	Negotiated Settlement 06/2015	LOC-14-001 Case No. VC060106	2013-2015

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	United States Steel Corporation In the Court of Common Pleas, Philadelphia County (Supporting Plaintiffs)				
Mr. Mark R. Staun The Segal Law Firm 810 Kanawha Boulevard, East Charleston, West Virginia 25301	Plaintiff(s): Steve Ansell Defendant(s): EXXON MOBIL CORPORATION, a New Jersey corporation; SAFETY-KLEEN SYSTEMS, INC., a Wisconsin corporation; RADIATOR SPECIALTY COMPANY, a North Carolina corporation; CRC INDUSTRIES, INC., a Pennsylvania corporation; WEST VIRGINIA, DEPARTMENT OF TRANSPORTATION, DIVISION OF HIGHWAYS, an agency of the State of West Virginia; NAZDAR COMPANY, Individually and as Successor-by-Acquisition/Merger to ADVANCE PROCESS SUPPLY CO., an Illinois corporation; ADVANCE PROCESS SUPPLY CO., an Illinois corporation; 3M COMPANY, a Delaware corporation; FUJIFILM NORTH AMERICA CORPORATION, as Successor-by Merger to FUJIFILM SERICOL U.S.A., INC., as Successor-by-Merger to SERICOL, INC., a New York corporation; UNCOMMON CONGLOMERATES, INC., a Division of CYBERBOND, LLC, a Delaware limited liability company Circuit Court of Marshall County, West Virginia (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 2015	SEG-13-001 Case No.: 13-C-119K	2013-2015
Mr. John Vincent Weston Hurd LLP 10 W. Broad St., Suite 400 Columbus, OH 43215	Plaintiff(s): Mercer Square, LLC Defendant(s): Preferred Real Estate Pre-Suite Inspection and Report (Supported Defendant)	Fire Suppression System Freeze Failure Jack Nicklaus Villa – 18th Green – Muirfield Village, Dublin, OH	Negotiated Settlement 2014	WES-14-001	2014
Mr. Darren Brown Provost Umphrey 490 Park Street Beaumont, TX 77704	Plaintiff(s): Carl Nolan Smith, III Defendant(s): Chevron U.S.A., Inc.; Chevron Chemical Company, LLC; ExxonMobil Oil Corporation; Texaco, Inc.; Atlantic Richfield Company; BP Amoco Chemical Company; BP Products North America, Inc.; Canadianoxy Offshore Production Co.; ConocoPhillips Company; Total Petrochemicals USA, Inc.; Union Oil Company of California; and Huntsman Petrochemical, Inc. 14th Judicial District Court, Parish of Calcasieu, State of Louisiana (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 10/2014	PRO-14-001 Cause No.: 2012-5290A	2014
Mr. Robert Black Black Law, PC The Lyric Centre	Plaintiff(s): Joseph Dwayne Meeks and Jane Meeks Defendant(s): Ace Hardware, British Petroleum (BP); E.I. du Pont de Nemours and Company (DuPont), Pittsburg Paint	Benzene Exposure	Negotiated Settlement 09/2015	BLA-14-001 Cause No.:	2014-2015

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
440 Louisiana, Suite 2400 Houston, Texas 77002	Glass (PPG), Savogran; Shell Oil Company (Shell); Sherwin-Williams Company (S-W), W.M. Barr & Company (WM Barr), and US Steel Company. Galveston County, Texas – 122nd District Court (Supported Plaintiffs)			14-CV-1044	
Mr. Scott R. Frieling Allen Stewart, P.C. 325 N. St. Paul St., Ste. 2750 Dallas, TX 75201	Plaintiff(s): Thomas Koenig and Rebecca Koenig Defendant(s): Ashland, Inc., BASF Corporation, Dow Chemical Company, Dynabrade, Inc., E.I. DuPont de Nemours & Co., Egyptian Lacquer Manufacturing Company, Inc., GE Betz, Inc., Henkel Corporation, NB Coatings, Inc., Zinsser Co., Inc. as successor to Parks Corporation, Plastic Process Equipment, Inc., Rohm & Hass Company, Worwag Coatings, LLC. In the Court of Common Pleas, Philadelphia County, PA (Supporting Plaintiff)	Benzene Exposure	Negotiated Settlement 04/2015	ALL-14-001 Cause No.: 12-12-03188	2014-2015
Mr. Scott R. Frieling Allen Stewart, P.C. 325 N. St. Paul St., Ste. 2750 Dallas, TX 75201	Plaintiff(s): Jerri A. Rowan Defendant(s): Sherwin-Williams, Inc., Columbia Forest Products, Inc., Futch Lumber, FTL Properties of Delaware, LLC, Baer Wurth, Aetna, Charter Industries, Temple-Inland, Inc., Tamarac Distributors, Charles F. Shiels, Bluelinx, Flagg, ATC Panels, Inc., Georgia Pacific Wood Products, Weyerhaeuser, Jeld-Wen, Inc., Custom Plywood, Rugby, Inc., Distributor Service, Inc., In the Court of Common Pleas, Cuyahoga County, OH (Supporting Plaintiff)	Benzene Exposure	Negotiated Settlement 01/2015	ALL-14-002 Cause No.: CV 13 813181	2014-2015
Mr. Peter Alfert Hinton Alfert & Kahn LLP 200 Pringle Ave., Suite 450 Walnut Creek, CA 94596	Plaintiff(s): Gavin Kirk, a minor by and through his guardian ad litem Stephen Tobin Kirk, Sarah Kirk, and Stephen Tobin Kirk individuals, Ryan Goode, a minor by and through his guardian ad litem James Goode, Jaqueline Goode and James Goode individuals Defendant(s): Varco International, Inc., Varco Heat Treating Company, Varco Oil Tools, National Oil Well Varco, Plazamerica Inc., Plaza National Real Estate, Inc., Plaza Atrium, Inc., Leed Plaza Atrium, LLC., successor in interest to Plazamerica, Inc., Leed Properties, Cove Properties, Inc., Cove Development Co., Cove Builders, Inc., County of Orange, and Does 1 through 200, inclusive. In the Superior Court of the State of California, for the County of Orange (Supporting Plaintiffs)	Soil/Gas Exposure Deposed by Defendant(s) 07/31/ 2015	Negotiated Settlement 02/2016	HIN-14-001 Cause No.: 30-2010-00423097 & 30-2011-00512364 Consolidated	2014-2016

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Timothy O'Brien Levin Papantonio 316 S. Baylen St.., #600 Pensacola, FL 32502 Mr. Robert Bilott Taft Stettinius & Hollister LLP 425 Walnut Street, Suite 1800 Cincinnati, OH 45202 Mr. Richard Schulte Wright & Schulte 812 E. National Road Vandalia, OH 45377	Plaintiff(s): C-8 Class Action Defendant(s): DuPont de Nemours United States District Court Southern District of Ohio – Eastern Division (Supporting Plaintiffs)	Exposure to C-8 Deposed by Defendant(s) 03/30/2015 Daubert Challenge by Defendant(s) – Denied August 6, 2015	Case 1 Bartlett - Testified in Trial 09/21, 22, 23/2015 Case 1 Decision in favor of Plaintiff Carla Bartlett 10/7/2015 Case 2 Freeman – Testified in Trial 06/10, 13, 14, 15/2016 Case 2 Decision in favor of Plaintiff David Freeman 07/08/2016 Case 3 Vigneron – Testified in Trial 12/1 & 5/2016 Case 3 Decision in favor of Plaintiff Keith Vigneron 01/05/2017 Case 4 Moody – 01/30, 31, and 02/ 1/2017 Case 4 Larry Moody - Part of Class Action Negotiated Settlement of 900 Million + 02/13/2017	WRI-14-001	2014-2017

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Emmett McGowan Nelson Brown & Co. 518 Township Line Road, Suite 300 Blue Bell, PA 19422	Plaintiff(s): Alva & Fern Hoopengardner Defendant(s): Meridian Citizens Mutual Insurance Company United States District Court Eastern District of Pennsylvania (Supported Defendant)	Indoor Air Quality (IAQ)	Negotiated Settlement 2014	NEL-14-001 Cause No.: 2:13-cv-07485-PD	2014
Mr. Scott R. Frieling Allen Stewart, P.C. 325 N. St. Paul St., Ste. 2750 Dallas, TX 75201	Plaintiff(s): Wade Wesley Wiederhold Defendant(s): Safety Kleen, Corp., Safety Kleen Systems, Inc., Rust-Oleum Corp., Berryman Products, Inc., ITW Permatex, a Division of Illinois Tool Works, Inc., The Valspar Corporation, Henkel Corporation, Deere & Company, Gold Eagle Co., The Sherwin-Williams Company, Apollo Industries, Inc., Claire-Sprayway, Inc., and Ozark Kenworth, Inc. In the Circuit Court of Jackson County, Missouri 2 at Independence (Supported Plaintiff)	Benzene Exposure Deposed by Defendant(s) 10/22/2015	Testified in Trial on 06/21/2016 Decision in favor of Defendant 07/2016	ALL-14-002 Case No.: 1316-CV13192	2014-2016
Mr. Andrew DuPont Locks Law Firm 1500 Walnut Street, 20th Floor Philadelphia, PA 19102	Plaintiff(s): Louis Arthur DeSorbo Defendant(s): United States Steel Corporation; Sunoco, Inc. (R&M) f/k/a Sun Company, Inc. and f/k/a Sun Oil Company, Inc.; 3M Company; Rogersol, Inc., Rycoline Products, Inc., a Division of Sun Chemical Commercial Group a/k/a Rycoline Products, LLC and Successor to Rogersol, Inc.; Sun Chemical Corporation, Individually and a Parent and Successor to Rycoline Products, LLC, a/k/a Rycoline Products, Inc. and Successor to Rogersol, Inc.; Van Son Holland Ink Corporation of American; Varn International, d/b/a Varn Products Company; Day International, Inc., Individually and as Successor to and d/b/a Varn Products Company; Printers Service d/b/a Prisco; Deleet Merchandizing Corporation; Cabrun Ink Products, Corporation; Handschy Industries, LLC; Chevron USA, Inc. Individually and as Successor In Interest to Unocal Corporation and its Subsidiaries; Philips Electronics North America Corporation d/b/a and a Parent and Successor In Interest .H. Agriculture and Nutrition, Inc. and Thompson-Hayward Chemical Company; Emco Chemical Distributors, Inc.; PPG Industries, Inc.; Shell Oil Company; Shell Oil Products US, INC.; Fisher Scientific International, Incorporated; Mallinckrodt Baker, Incorporated, Individually and as Successor In Interest to J.T. Baker, Incorporated; Total Petrochemicals & Refining USA, Incorporated, Individually and as Successor In Interest to American Petrofina, Inc. Total Plaza a/k/a FINA, Inc., Cosden Oil Company, Graphic Packaging International, Inc. Individually	Benzene Exposure	Testified in Trial 02/10/2016 Decision in Favor of Plaintiff 02/2016	LOC-14-002 Cause No. 003450	2014-2016

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	and Successor in Interest to Handschy Industries, LLC.; Anchor/Lith-Kem-Ko, Incorporated, a Subsidiary of FugiFilm Hunt Chemicals USA, Incorporated; FugiFilm Hunt Chemicals USA, Incorporated, d/b/a and Parent and Successor to Anchor/Lith-Kem-Ko, Incorporated; Sinclair & Valentine Company, Incorporated; Hurst Chemical Company; Gans Ink & Supply Company, Incorporated; Spinks Ink Company, Incorporated; Flint Ink Corporation; et al. In the Court of Common Pleas, Philadelphia County, Pennsylvania (Supported Plaintiff)				
Allen Stewart Stephanie Sherman 325 N. St. Paul St., Suite 2750 Dallas, TX 75201	Plaintiff(s): Christopher Lightfoot Defendant(s): Georgia-Pacific Wood Products LLC, Georgia-Pacific, LLC, individually and as successor-in-interest to Georgia-Pacific Corporation, Weyerhaeuser Company, Weyerhaeuser NR Company, Lowes Home Centers, LLC (NC), and John Doe 1 State Court of Fulton County, GA (Supported Plaintiff)	Wood Dust Exposure	Negotiated Settlement 2016	ALL-15-001 Cause No.: 01960	2015-2016
Mr. Darren Brown Provost Humphrey P.O. Box 4905 Beaumont, Texas 77704	Plaintiff(s): Cathy Withers Defendant(s): Chevron U.S.A., Texaco, Inc., Union Oil Company of California, Alon USA, LP, Anadarko E & P Onshore, LLC, ConcoPhillips Company, ExxonMobil Oil Corporation, PB Amoco Chemical Company, BP Products North America, Inc., Canadianoxy Offshore Production Company, Citgo Petroleum Corporation, Delek Logistics Operating, LLC, Total Petrochemicals & Refining, USA,, Inc., El Paso Energy E.S.T. Company, El Paso Natural Gas Company, LLC, Enbridge Marketing LLC, Targa Resources, Axiall Georgia Gulf Corp., Hunt Oil Company, et al. In the 14th Judicial District Court for the Parish of Calcasieu, State of Louisiana, Division "D"	Benzene Exposure	Negotiated Settlement 12/2016	PRO-15-001 Cause No.: 2013-3723	2015-2016
Kohrman Jackson & Krantz Ms. Heather Zilka 10 West Broad Street, Suite 1900 Columbus, OH 43215	Plaintiff(s): Mary Christian Defendant(s): Lawrence Water, et al. Lawrence County Common Pleas, Ohio (Supported Defendant)	Structural Damage from Water Leak	Negotiated Settlement 10/2016	KJK (SMI)-15-001 Cause No.: 14 OC 739	2015-2016
Mr. Everett Day Black Law, PC The Lyric Centre 440 Louisiana, Suite 2400 Houston, Texas 77002	Plaintiff(s): Yomanoh Akpobo Defendant(s): Ross Dress for Less, Inc., Houston, TX American Arbitration Association Arbitration Proceedings – Employment Arbitration	Slip & Fall	Negotiated Settlement 07/2017	BLA-15-001 Cause No.: 01-15-0005-2333	2015-2017

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	(Supported Plaintiff)				
Mr. John E. Tomlinson Beasley, Allen, Crow, Methvin, Portis & Miles, P.C. 218 Commerce Street Montgomery, AL 36104	Plaintiff(s): Sheila D. Keenum, Individually, and as Personal Representative of the Estate of Wendell Joe Keenum, deceased Defendant(s): E. I. du Pont de Nemours and Company; PPG Industries, Inc.; SEM Products, Inc.; The Valspar Corporation; Rust-Oleum Corporation; O'Reilly; Automotive Stores, Inc.; R. & R. Bumper & Body Supply, Inc.; Detail Supply, LLC; Sam T. Carter Oil Company, Inc.; The Sherwin-Williams Company; Hunt Refining Company; One Shot LLC; Cumberland Products Incorporated; Powers Paper Company, and Fictitious Defendant(s) "1 through 100. In the Circuit Court of Colbert County, Alabama. (Supported Plaintiff)	Exposure to Paint Products Deposed by Defendant(s) 09/30/2020	On-going	BEA-16-001 Case #: 20-CV-2016-900050.	2016-Present
Mr. Chris Heavens Heavens Law Firm PLLC 2438 Kanawha Blvd., East Charleston, WV 25311	Plaintiff(s): Dominick Hall Defendant(s): Silicon Processors, Inc. In the Circuit Court of Wood County, WV (Supported Plaintiff)	Personal Injury Deposed by Defendant(s) 08/09/2017	Negotiated Settlement 10/2017	HEA-15-001 Case No: 15-C-471	2015-2017
Mr. Andrew Lipton Hobson & Bradley 2190 Harrison Beaumont, TX 77701	Plaintiff(s): Herbert C. Cowart Defendant(s): ExxonMobil, Hess, Chevron/Texaco, Keystone Shipping, ConocoPhillips, Canadianoxy Offshore Production Company, Coastal Fuels Marketing Company, Shell Oil Company, Union Carbide Corporation, Signet Maritime Corporation, Kirby Inland Marine, LP, BP Products North America, Marathon Oil Company 14th Judicial District Court, Parish of Calcasieu, State of Louisiana, Division E (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 07/2017	HOB-16-001 Cause No.: 2004-3133	2016-2017
Ms. Jo Anna Pollock The Simmons Firm One Court Street Alton, IL 62002	Plaintiff(s): Gerald Dean Maberry Defendant(s): Shell Oil Company, Equilon Enterprises, LLC, d/b/a Shell Oil Products, US; ConocoPhillips Company; WRB Refining LP; ConocoPhillips WRB Partner LLC; Cenovus GPCO LLC; and, BP Products North America, Inc. In the Circuit Court for the Third Judicial Circuit, Madison County, IL (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 09/2016	SIM-16-001 Case No.: 15-L-1193	2016
Mr. Robert Black Black Law, PC The Lyric Centre 440 Louisiana, Suite 2400	Plaintiff(s): Gregory A. Justice et al. Defendant(s): Radiator Specialty (DuPont), Savogran; Shell Oil Company (Shell); Sherwin-Williams Company (S-W), W.M. Barr & Company (WM Barr), and US Steel Company	Benzene Exposure	Negotiated Settlement 02/2017	BLA-16-001 Cause No.: 15-CV-0907	2016-2017

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Houston, Texas 77002	In the District Court of Galveston County, TX – 112nd Judicial District (Supported Plaintiffs)				
Mr. Robert Black Black Law, PC The Lyric Centre 440 Louisiana, Suite 2400 Houston, Texas	Plaintiff(s): Nin Koy Defendant(s): Steel Masters, LP, Steel Masters-GP LLC, and J.T. Vaughn Construction, LLC. In the District Court of Harris County, TX – 190th Judicial District (Supported Plaintiff)	Personal Injury - Finger Amputation	Negotiated Settlement 10/2016	BLA-16-002 Civil Cause No: 2015-01-01775	2016
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Lee D. Tanked, Jr. and Cheryl Tankard, his wife. Defendant(s): Advance Auto Parts, Inc.; A.E. Lottes, Co., f/k/a Carquest Auto Parts #1, Inc. d.b.a. Carquest Store #2856; CQ Sourcing, Inc.; Walker Automotive Supply, Inc.; Safety-Kleen Systems, Inc.; CRC Industries, Inc.; 3m Company; and The B'Laster Corporation. In the General Court of Justice, Superior Court Division State of North Carolina, Wake County (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 02-01-2020	HAR-16-002 Civil Cause: 16-CVS-2949	2016-2020
Mr. David J. Carney Anapol Weiss One Logan Square 130 N. 18th St. Suite 1600 Philadelphia, PA 19103	Plaintiff(s): David S. Garrison and Laura Timmes-Garrison Defendant(s): Smiths Group, PLC; Saint-Gobain North America, d/b/a Saint-Gobain Performance Plastic Corporation, successor in interest to CHR Industries, Inc., and Dixon Industries Corporation, successor in interest to Penntube Plastics; Compressor Products International, LLC, successor in interest to Plastomer Products; Quaker City Chemicals, Inc.; Exxon Mobil Corporation; E.I DuPont de Nemours and Company, Inc. and W.N. Stevenson, Company Philadelphia County Court of Common Pleas, PA (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 03/2018	ANA-16-001 Case No.: 001960	2016-2018
Mr. Chris Heavens Heavens Law Firm PLLC 2438 Kanawha Blvd., East Charleston, WV 25311	Plaintiff(s): Walter H. Jones, Jr. Defendant(s): Family Handyman Services of Barboursville, LLC, George E. Linkous, individually and as owner of Family Handyman Services of Barboursville, LLC, and Absolut Roofing, LLC In the Circuit Court of Kanawha County, WV (Supported Plaintiff)	Personal Injury – Fall from Roof	Negotiated Settlement 10/2017	HEA-16-001 Case No.: 15-C-2059	2016-2017
Mr. Chris Heavens Heavens Law Firm PLLC 2438 Kanawha Blvd., East Charleston, WV 25311	Plaintiff(s): Paul Michalec and Jennifer Michalec Defendant(s): American Supply Company, Inc. In the Court of Common Pleas, Philadelphia County, PA	Personal Injury – Loading Dock Injury	Testified in Trial 07/07/2017 Decision by	HEA-16-003 Civil Cause No. 000893	2016-2017

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	(Supported Plaintiffs)		Jury for the Plaintiffs $573,000 07/17/2017		
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Mark A. Fitzpatrick and James Parrish and Monica Parrish, his wife Defendant(s): SAL Chemical Co., Inc., an Ohio Corporation, Chemical Solvents, Inc. an Ohio Corporation, Ball Aerosol and Specialty Containers Inc, f/k/a United States Can Company, an Indiana Corporation, Mall Metal Food Container, LLC f/k/a Ball Metal Food Container Corp., a Delaware LLC. In the Circuit Court of Brooke County, West Virginia (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 01/2018	HAR-16-002 Case No,: 14-C-74	2016-2018
Mr. Chris Heavens Heavens Law Firm PLLC 2438 Kanawha Blvd., East Charleston, WV 25311	Plaintiff(s): Heckler Defendant(s): Ricottilli Lumber Company, Inc. Pre-Lawsuit (Supported Plaintiff)	Personal Injury – Sawmill Operations Accident	Cancelled	HEA-16-005	2016-2017
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Jack S. Edison Defendant(s): CSX Transportation, Inc., individually and as successor-in-interest to Louisville & Nashville Railroad Company In the Circuit Court of Hamilton County, Tennessee (Supported Plaintiff)	Diesel fuel & Exhaust	Negotiated Settlement 08/2017	MOT-16-003 Case No.: 15-C-1407, Division 2	2016-2017
Ms. Jo Anna Pollock Simmons Hanly Conroy One Court Street Alton, IL 62002	Plaintiff(s): Joan Green, on behalf of the Estate of Thomas Albert Green, Deceased Defendant(s): 3M Company, Apex Oil Company, Inc., Clark Oil & Refining Corporation, Premcor Refining Group, Inc., Radiator Specialty Company, Safety-Kleen Corporation, Safety-Kleen Systems, Inc., Turtle Wax, Inc., United States Steel Corporation, et al In the Circuit Court Third Judicial Circuit, Madison County, Illinois (Supported Plaintiff)	Benzene Exposure	Negotiated Settlement 10/31/2018	16-004 Case No.: 15-L-1418	2016-Present
Mr. David J. Carney Anapol Weiss One Logan Square 130 N. 18th St. Suite 1600 Philadelphia, PA 19103	Plaintiff(s): Jean Nelson, Executrix of the Estate of Charles Nelson, III, Deceased Defendant(s): BP Products North America, Inc. individually and as successor in interest to the Standard Oil Company d/b/a SOHIO In the United States District Court for the Eastern District of	Benzene Exposure Deposed on 06/28/2018	Negotiated Settlement 2018	ANA-16-002 Case No.: 2:16-CV-04888-JP	2016-Present

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Pennsylvania (Supported Plaintiff)				
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Jesse D. Roop Defendant(s): CSX Transportation, Inc., Individually and as Successor-in-Interest to Seaboard System Railroad, Seaboard Coast Line Railroad, Seaboard Air Line Railroad and Atlantic Coast Line Railroad State Court of Chatham County, Georgia (Supported Plaintiff)	Diesel Fuel & Exhaust/Benzene Deposed on 06/06/2019 Daubert Hearing 6/6/2020 – Motion Denied	Loss Summary Judgment 06/2020	MOT-16-001 Case No. STCV1600137S A	2016-2020
Mr. Colin King Dewsnup King & Olsen Law 36 South State Street, Suite 2400 Salt Lake City, UT 84111-0024	Plaintiff(s): Allan Flandro Defendant(s): Chevron Pipe Line Company, a Delaware Corporation; PacifiCorp, an Oregon Corporation dba Rocky Mountain Power; and Corporation of the President of the of the Church of Jesus Christ of Latter-Day Saints. Third Judicial District Court, Salt Lake County, Utah (Supported Plaintiff)	Chemical Exposure	Negotiated Settlement 03-01-2021	DEW-16-001 Case No. 180905235	2016-2021
Mr. David J. Carney Anapol Weiss One Logan Square 130 N. 18th St. Suite 1600 Philadelphia, PA 19103	Plaintiff(s): James R. Meyer (deceased) and Jeanette Meyer Defendant(s): Atlantic Richfield Company, BP Products North American, Inc., Chevron USA Inc. f/k/a Gulf Oil Corporation, Hess Corporation, ExxonMobil Oil Corporation, Sun Oil Company d/b/a Sunoco Incorporated, Exelon Corporation as parent to Philadelphia Electric Company, Philadelphia Gas Workers, Arcelormittal USA, LLC, United States Steel Corporation, Rohm & Haas Company, J.J. White Incorporated, Nooter Construction Company, Frank Lill & Son, Incorporated, United States Services Group, and Foster Wheeler Zack, Inc. Court of Common Pleas Philadelphia County, PA, Civil Division Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 01/2018	ANA-16-002 Case No. 15-07 -02328	2017-2018
Mr. Guy Bucci Bucci Bailey & Javins LC 112 Capitol Hill, Suite 200 Charleston, WV 25301	Plaintiff(s): Jo Ann Gore Defendant(s): The Kroger Company, an Ohio Corporation United States District Court for the Southern District of West Virginia at Charleston (Supported Plaintiff)	Personal Injury – Fall in Store	Negotiated Settlement 07/2017	BUC-17-001 Civil Action No.: 2:16-cv-09223	2017
Mr. Robert Black Black Law, PC The Lyric Centre 440 Louisiana, Suite 2400 Houston, Texas	Plaintiff(s): Leo Lippold and Stacy Lippold Individually, and as next friends for XXXXX XXXXXXX, a Minor Defendant(s): A-Pro Top Construction, RRE Armand Place Holding, LLC and Resource Real Estate Management Company In The District Court of Harris County, Texas 152nd Judicial District. (Supported Plaintiffs)	Personal Injury – Pool Fence Injury to Child – Spike Through Neck	Negotiated Settlement 10/2017	BLA-17-001 Cause No.: 2016-11087	2017

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Brian Fritz Fritz Goldenberg & Bianculli 1515 Market Street, Suite 705 Philadelphia, PA 19102	Plaintiff(s): Thomas Timlin and Wendy Timlin, H/W Defendant(s): BP America, Inc., a/k/a BP Corporation, a/t/a Tosco, Sunoco, Inc. (R&M); Sunoco Partners Marketing and Terminals, LP; Sunoco Logistics Partners, LP; Sunoco Partners, LLC; Sunoco Chemicals, Inc.; Conoco Phillips; Phillips Petroleum Company; Chevron U.S.A, Inc.; Chevron Corporation; Braskem American, Inc.; Braskem S/A; Philadelphia Energy Solutions, LLC; Philadelphia Energy Solutions Refining & Marketing, LLC; Energy Transfer Partners GP, LP; Energy Transfer Partners, LLC; Energy Transfer Partners GP, LP; Citrus Corporation; Kinder Morgan, Inc., The Carlyle Group, LP; Carlyle Management Group Partners, LP; Carlyle Group Management, LLC; Epsilon Products Company, LLC; Honeywell, Inc.; Honeywell International, Inc.; Monroe Energy, LLC; Monroe Energy a/k/a MIPC, LLC, and/or MIPC, LLC. Court of Common Pleas Philadelphia County, PA (Supported Plaintiffs)	Benzene Exposure	Negotiated Settlement 02/2018	FRI-17-001 Case No.: 15-06-062709 Docket No.: 004033	2017-2018
Mr. Chris Heavens Heavens Law Firm PLLC 2438 Kanawha Blvd., East Charleston, WV 25311	Plaintiff(s): Darrell Fint Defendant(s): Brayman Construction, a Foreign Corporation In the United States District Court for the Southern District of West Virginia (Supported Plaintiff)	Personal Injury	Negotiated Settlement 04/2019	HEA-17-001 Civil Action No. 5:17-CV-04043	2017-2019
Mr. Andrew Lipton Hobson & Bradley 2190 Harrison Beaumont, TX 77701	Plaintiff(s): Arthur Whitfield Defendant(s): Alaska Tanker Company; Alyeska Pipeline Service Company; BP American Inc.; BP Amoco Chemical Company; BP Corporation North America, Inc.; BP Pipelines (Alaska), Inc.; BP Pipelines (North America), Inc.; BP Products North America, Inc.; Chevron Corporation, individually and as successor to Union Oil Company of California (Unocal) and Unocal Pipeline Company; Chevron USA, Inc.; ConocoPhillips Alaska, Inc.; ConocoPhillips Company; ConocoPhillips Transportation Alaska, Inc.; Crowley Marine Services, Inc., individually and as successor to Marine Transport Lines; Crawley Maritime Corporation, individually and as successor to Marine Transport Lines; Hess Corporation; Keystone Shipping Company, individually and successor to Shipco 669 Inc. and Shipco 2296 Inc.; Marine Transport Lines, Inc.; Petro-Diamond, Inc.; Petro-Diamond Terminal Company; Phillips 66 Company; Phillips 66 Pipeline, LLC; and Shell Chemical, LP. In the District Court of Jefferson County, TX, 172nd Judicial District (Supported Plaintiff)	Benzene Exposure	On-Going	HOB-17-001 Cause No: E-198,379	2017-Present

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Todd McPharlin Kelley Uustal 500 N. Federal Highway, Suite 200 Fort Lauderdale, FL 33301	Plaintiff(s): Polly O'Hara Defendant(s): HomeGoods, Inc. and Martha Prophete In the Circuit Court of the 17th Judicial Circuit in and for Broward County, Florida (Supported Plaintiff)	The standard of care required to protect workers and customers. Deposed on 04/12/2017	Negotiated Settlement 05/2018	KEL-17-001 Case No.: CACE16-007612	2017-2018
Mr. Craig Harris Trentalange & Kelley, P.A. 218 N. Dale Mabry Highway Tampa, FL 33609	Plaintiff(s): James R. Barber Defendant(s): Precision Shooting Equipment, Inc. In the Circuit Court of the Thirteenth Judicial Circuit in and for Hillsborough County, Florida (Supported Plaintiff)	PSE TAC Elite Crossbow Failure Deposed on 06/30/2017	Negotiated Settlement 05/2018	TRE-17-001 Case No. 2016-CA-005728-G	2017-2018
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Judith Rosser, Individually and as Executrix of the Estate of Hayden Eugene Rosser, Dec Defendant(s): Norfolk Southern Railway Company, Individually and as Successor to Southern Railway Company, A Virginia Corporation In the United States District Court for the Middle District, North Carolina	Diesel Fuel & Exhaust and Benzene Deposed on 11/28/2017	Negotiated Settlement 05/2018	MOT-17-003 Case No.: 1: 16-CV-4-01	2017-2018
Mr. Guy Bucci Hendrickson & Long PLLC 112 Capitol Hill, Suite 200 Charleston, WV 25301	Plaintiff(s): Cantrell Defendant(s): STAT Pre-Lawsuit (Supported Plaintiff)	Personal Injury (Slip, Trip and Fall) Prepared Report	Negotiated Settlement 10/2018	HEN-17-002	2017-2018
Mr. Brian Madden Wagstaff & Cartmell, LLP 4740 Grand Avenue, Suite 300 Kansas City, MO 64112	Plaintiff(s): Mary Johnson et al. Defendant(s): Zill, LLC, MHS Environmental, Inc., et al. & The City of Kansas City, MO; The Kansas City Public Schools USD 33 a/k/a Kansas Public Schools, Land Bank of Kansas City Missouri, Brandon Dixon and Tiara Dixon, Inner City Oil Company, Inc. and Renee Wiggs and Bill Wiggs (third-party Defendant(s)) In The Circuit Court of Jackson County, Missouri at Kansas City (Supported Plaintiff)	Petroleum Contamination at/near Home Deposed on 12/06/2017	Negotiated Settlement 10/2018	WAG-17-001 Case No.: 1616-CV01151	2017-2018
Mr. Lon Walters The City Market 23A East Third Street Kansas City, MO 64106	Plaintiff(s): James Petrechko Defendant(s): BP Corporation North America Inc. and BP Products North America Inc. – Former American Oil Company (AMOCO) Site In the Circuit Court of Jackson County, Missouri at Independence (Supported Plaintiff)	Benzene Exposure Deposed on 1/10/2018	Negotiated Settlement 03/2018	WAL-17-001 Case No.: 1616-CV26094	2017-2018
R. Dean Hartley Hartley Law Group, PLLC	Plaintiff(s): Elijah P. Morris and Shirley J. Morris, his wife Defendant(s): Constellium Rolled Products Ravenswood,	Aromatic, Chlorinated, and	Negotiated Settlement	HAR-17-004	2017-2018

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	LLC, individually and as successor-in Interest to Kaiser Aluminum, Corporation, Ravenswood Aluminum Corporation, Century Aluminum Corporation of West Virginia, Inc., Pechiney Rolled Products, LLC, Alcan Rolled Products-Ravenswood, Rio Tinto Alcan, Inc., and Apollo Global Management, LLC, a Delaware Limited Liability Company et al. In the Circuit Court of Jackson West Virginia (Supported Plaintiffs)	Various Cutting Oils, Mists	2018	Civil Action No. 14-C-80	
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Wendy Smith, Individually and as Personal Representative for the Estate of Jeremy O. Smith, Deceased Defendant(s): CAN Holdings, Inc. et al. State of South Carolina, County of Spartanburg, Court of Common Pleas, Seventh Judicial Circuit (Supported Plaintiff)	Diesel Fuel & Exhaust/Benzene Deposed on 6/04/2019	Negotiated Settlement 08/2019	MOT-17-004 Case No.: 2017-CP-4202983	2017-2019
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Dora Carbajal de Vences and Jose Luis Vences Sotelo, her husband Defendant(s): MAAX US Corp., Individually and as Successor-in-Interest by Aker Plastics Co., Inc., a Delaware Corporation; AOC, LLC; Arkema, Inc.; Axson US, Inc.; CTG International; Edgemate, Inc.; Evonik Corp.; Illinois Tool Works, Inc.; Jotun Paints, Inc.; Jowat Corporation; The Matchless Metal Polish Company; Multi-Tech Products, LLC; Performance Mineral Corp.; Sasol Chemicals North America, LLC; TR Industries, LLC; 3M Company, Individually and as Successor-by-Merger for/to Bondo Company; US Compliance Corp. In the Circuit Court of Berkley County, West Virginia (Supported Plaintiffs)	Chemical Exposure Deposed 06/25-26, 2019	Negotiated Settlement 01/2020	HAR-17-002 Case No.: 17-C-98	2017-2020
Ms. Diana H. Crutchfield Berry, Kessler, Crutchfield, Taylor and Gordon 514 Seventh Street Moundsville, WV 26041 Mr. Guy Bucci Hendrickson & Long 214 Capitol Street Charleston, WV 25301	Plaintiff(s): Mr. Frank David Fullerton and Penny K. Fullerton Defendant(s): Bayer Corporation, an Indiana Corporation; Bayer MaterialScience, LLC, a Delaware Corporation; Covestro, LLC, a Delaware Corporation; Robert Baxter, Individually; Gary Durig, Individually; and Robert Greathouse, Individually Circuit Court of Marshall County, West Virginia (Supported Plaintiffs)	TDI Exposure Deposed on 06/13/2019	Negotiated Settlement 09/2020	BER-17-001 Civil Action No.: 11-C-197 K	2017-2020
Ms. Jo Anna Pollock Simmons Hanly Conroy One Court Street Alton, IL 62002	Plaintiff(s): James Andrew Spalo, an individual; and Mary Spalo, an individual Defendant(s): Union Pacific Railroad Company, Safety-Kleen Corporation, and Safety-Kleen Systems, Inc., et al.	RR Worker Deposed on 01/18/2019	Negotiated Settlement 02/2019	SIM-18-001 Case No.: 2017 L 3103	2018-2019

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	In the Circuit Court of the First Judicial Circuit, Cook County, State of Illinois (Supported Plaintiffs)				
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Judy Caruthers, Individually and as Administratrix of the Estate of Johnny Caruthers, Deceased Defendant(s): 3M Company, a Delaware Corporation; Ashland, LLC, a Kentucky Corporation; B'Laster Corporation, an Ohio Corporation; Castle Product, Inc., a New York Corporation; CRC Industries, Inc., a Pennsylvania Corporation; Exxon Mobil Corporation, a New Jersey Corporation; General Truck Sales Corporation, a West Virginia Corporation; Genuine Parts Company, D/B/A NAPA Auto Parts, a Georgia Corporation; Henkel Corporation, a Delaware Corporation; ITW Polymers Sealants North America, Inc., D/B/A ITW Pro Brands and or LPS, a Texas Corporation; Oliver Fuels & Oils, Inc., a West Virginia Corporation; Radiator Specialty Company, a North Carolina Corporation; Safety-Kleen Systems, Inc., a Wisconsin Corporation; Shamrock Specialties, Inc., a Texas Corporation; Walker Machinery, Co., a West Virginia Corporation; and ZEP, Inc., a Delaware Corporation, Defendant(s) In the Circuit Court of Putnam County, West Virginia. Honorable Judge Stowers (Supported Plaintiff)	Benzene Exposure	On-going	HAR-17-003 Case No.: 18-C-83	2017-Present
Weitz & Luxenberg P.C. Ms. Robin Greenwald Mr. Jerry Kristoff 700 Broadway New York, NY 10003 Levin Papantonio Thomas Mitchell Rafferty & Proctor, P.A. 316 South Baylen Street Pensacola, FL 32502	Plaintiff(s): Chaplick, Kyle; Cole, Dean; Cook, Bryan; Gatewood, Stephen; Gatewood, Vicki; Haley, Richard; Hammond, Marcus; Jenkins, Lafayette; Karr, Joshua; Miller, Robert; Puchbauer, Michael; Sanders, Deion; Sessions, Joseph; Winston, Walter. Defendant(s): Monsanto Company In the Circuit Court of the City of St. Louis, State of Missouri (Supported Plaintiffs)	Exposure to Roundup Deposed 7/9, 10, & 11/2019 & 7/25-26/2019 Daubert Motion filed on 9/11/2019; – never ruled on.	Negotiated Settlement 06/2020	LEV-18-001 Case No.: 1822-CC00515	2018-2020
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Thomas E. Kemp, Jr. and Kelly Kemp, his wife Defendant(s): Sal Chemical Company, Inc. an Ohio Corporation; Superior Solvents, Inc. (Superior Oil Company, Inc.), d/b/a Superior Solvents and Chemicals, an Indiana corporation; The Valspar Corporation, a Delaware corporation; Karcher North America, Inc., d/b/a Hotsy, a Delaware corporation; Tier Environmental Services, Inc., as successor-in-interest to Hukill Chemical Corporation, a Delaware corporation; Jenkin-Guerin, Inc., a Missouri	Exposure to Chemicals Deposed on 1/23/2019	Negotiated Settlement 07/2019	HAR-18-002 Civil Action No.: 16-C-21	2018-2019

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	corporation; ZEP Inc., as successor-in-interest to Selig Industries, a Delaware corporation; The Sherwin-Williams Company, an Ohio corporation; and Acuity Specialty Products, Inc. a Georgia corporation. In the Circuit Court of Brooke County, West Virginia. Honorable Ronald E. Wilson. (Supported Plaintiffs)				
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Donald August Alexander and Fran Alexander, his Wife. Defendant(s): Koppers, Inc., a Pennsylvania Corporation; Southeast Ohio Auto Parts, Inc., d/b/a NAPA of Wellsburg, a Georgia Corporation; Kano Laboratories, Inc., a Tennessee Corporation; Sal Chemical Co., Inc., an Ohio Corporation; CRC Industries, Inc., a Pennsylvania Corporation; The B'Laster Corporation, an Ohio Corporation; and Safety-Kleen Systems, Inc., a Wisconsin Corporation. In the Circuit Court of Brooke County, West Virginia. (Supported Plaintiffs)	Exposure to Chemicals Deposed on 1/27/2021	On-Going	HAR-18-003 Civil Action No.: 16-C-35	2018-Present
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Jay Bradford Crofford Defendant(s): Koppers, Inc., a Pennsylvania Corporation; Southeast Ohio Auto Parts, Inc., d/b/a NAPA of Wellsburg, a Georgia Corporation; Kano Laboratories, Inc., a Tennessee Corporation; Sal Chemical Co., Inc., an Ohio Corporation; CRC Industries, Inc., a Pennsylvania Corporation; The B'Laster Corporation, an Ohio Corporation; and Safety-Kleen Systems, Inc., a Wisconsin Corporation. In the Circuit Court of Brooke County, West Virginia (Supported Plaintiff)	Exposure to Chemicals	On-Going	HAR-18-004 Civil Action No.: 18-C-78	2018-Present
Metzger Law Group Raphael Metzger 401 E. Ocean Blvd., Ste. 800 Long Beach, CA 90802	Plaintiff(s): Johnny Nelson Blake and Kathleen Mary Blake Defendant(s): Akzo Nobel Coatings, Inc., as successor by acquisition to Devoe Coatings and Sinclair Paint Company, an Illinois Corporation; Benjamin Moore & Company, a New Jersey Corporation; Carboline Company, a Missouri Corporation; Castrol Industrial North America, Inc., a Texas Corporation; Dunn-Edwards Corporation, a California Corporation; Ellis Paint Company, a California Corporation; Ennis-Flint as successor by acquisition to Pervo Paint Company, a North Carolina Corporation; Illinois Tool Works, Inc., a Delaware Corporation; Jotun Paints, Inc., a Louisiana Corporation; Magnaflux Corporation, a Delaware Corporation; PPG Industries, Inc., as successor by acquisition to Ameron International Protective Coatings Group, a Pennsylvania Corporation; Rexnord Corporation, as successor by	Benzene Exposure	Negotiated Settlement 04/2019	MET-18-001 Case No.: BC616881; Honorable Terry A. Green, Dept. 14	2018-2019

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	acquisition to the Falk Corporation, a Wisconsin Corporation; Rust-Oleum Corporation, an Illinois Corporation; Safety-Kleen Systems, Inc., a Massachusetts Corporation; The Steco Corporation, an Arizona Corporation; Pervo Paint Company, a California Corporation (previously sued herein as Doe #1); BASF Corporation, a Delaware Corporation (previously sued herein as Doe #2); PFI, Inc., a California Corporation (previously sued herein as Doe #3); PPG Industries, Inc. a Pennsylvania Corporation (previously sued herein as Doe #4); The Valspar Corporation, a Delaware Corporation (previously sued herein as Doe #5); The Sherwin-Williams, Company, an Ohio Corporation (previously sued herein as Doe #6); Tyco International (US), Inc., a Massachusetts Corporation (previously sued herein as Doe #7); W. M. Barr & Company, Inc. a Tennessee Corporation (previously sued herein as Doe #8); CRC Industries, Inc., a Pennsylvania Corporation (previously sued herein as Doe #9); 3M Company, a Delaware Corporation (previously sued herein as Doe #10); Aervoe Industries, Inc. a Nevada Corporation (previously sued herein as Doe #11); Krylon Products Group, an Ohio Corporation (previously sued herein as Doe #12); Axalta Coating Systems, LLC, as successor by acquisition to Pacific Coats Lacquer, a Delaware Limited Liability Company (previously sued herein as Doe #13); Seymour of Sycamore, Inc., an Illinois Corporation (previously sued herein as Doe #14); and Does 15-200, Inclusive. In the Superior Court of the State of California, County of Los Angeles, Central District (Supported Plaintiffs)				
Mr. Lon Walters The Walters Law Firm The City Market 23A East Third Street Kansas City, MO 64106	Plaintiff(s): Peggy Petrovic, Individually and as Plaintiff ad litem for Alexander Petrovic, Jr., deceased Defendant(s): BP Corporation North America Inc. and BP Products North America Inc. – Former American Oil Company (AMOCO) Site. Circuit Court of Jackson County, Missouri at Independence (Supported Plaintiffs)	Benzene Exposure Deposed on 3/13/2020	On-going	WAL-18-001 Cause No.: 1716-cv24363; Division 5	2018-Present
Mr. Jeff Gaddy Mr. Wesley Bowden Levin Papantonio 316 Baylen Street Pensacola, FL 32502	Plaintiff(s): Wayne D. McClung Defendant(s): E.I. du Pont de Nemours and Company Circuit Court of Wood County, West Virginia (Supported Plaintiff)	C-8 Exposure	Negotiated Settlement 03/2019	LEV-18-002 Civil Action No.: 17-C-223	2018-2019
Mr. Guy Bucci Mr. Scott Long Hendrickson & Long PLLC	Plaintiff(s): EQT Gathering, LLC Defendant(s): The Travelers Indemnity Company and	Gas Pipeline Explosion Wrongful Death	Negotiated Settlement 04/2019	HEN-18-001 Civil Action No.	2018-2019

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
214 Capitol St. Charleston, WV 25301	Travelers Casualty Company of America In the United States District Court for the Southern District of West Virginia at Charleston (Supported Plaintiff)			2:18-cv-00392	
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Roach Defendant(s): CSX, Seaboard Coastline and Atlantic Coastline (Supported Plaintiff)	Diesel Fuel, Herbicides, Fungicides, Fertilizers, Spectracide, Pesticides and Organic Chemicals	Negotiated Settlement 01/2021	MOT-18-005	2018-2021
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Logan Dodd Defendant(s): L&N/CSX Railroad (Supported Plaintiff)	Diesel Fuel & Exhaust/Benzene/ Asbestos	Negotiated Settlement 04/2021	MOT-18-004	2018-2021
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Dale E. Price, Executor of the Estate of Gary E. Price, Deceased. Defendant(s): Consolidated Rail Corporation a/k/a American Premier Underwriters, Inc., Individually and as Successor-in-Interest-or-Liability to Penn Central Transportation Company, and/or The Pennsylvania Railroad Company In the Court of Common Pleas of Allegheny County, PA – Civil Action – Asbestos (Supported Plaintiff)	Diesel Fuel, Diesel Exhaust, Creosote, and Asbestos	On-going	MOT-18-002 Case No.: GD 19-006889	2018-Present
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Edward Arthur Johnson Defendant(s): CSX Transportation, Inc., Individually and as Successor-in-Interest to Louisville & Nashville Railroad Company and Seaboard Coast Line Railroad In the Circuit Court of Davidson, Tennessee (Supported Plaintiff)	Diesel Fuel & Exhaust/Benzene/ Asbestos	On-going	MOT-18-001 Case No. 19C105	2018-Present
J. Robert Black Black Law, PC 3701 Kirby Dr., Suite 101 Houston, TX 77098	Plaintiff(s): Eva Garcia Gonzales, Individually and as Personal Representative of the Estate of Ricardo S. Gonzales, deceased; Katherine G. Sanchez; Amanda Gonzales-Todd; and Joseph P. Gonzales. Defendant(s): Waukesha-Pearce, LLC; Ace Hardware Corporation; Berryman Products, Inc.; BP Amoco Chemical Company; BP Products North America, Inc.; BP Corporation North American, Inc.; Chevron, USA, Inc.; CRC Industries, Inc.; CTR Petroleum, Inc.; The Dow Chemical Company; E. I. DuPont De Nemours & Company; ExxonMobil Oil Corporation; Radiator Specialty Company; Safety-Kleen Corp., Safety-Kleen Systems, Inc.; Shell Oil, Co.; Total	Benzene Exposure	Negotiated Settlement 05/2019	BLA-18-001 Case No: 2018-21475	2018-2019

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Petrochemicals & Refining USA, Inc.; Union Oil Company of California; United States Steel Corporation. In the District Court of Harris County, Texas, 281st Judicial District. (Supported Plaintiffs)				
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): James Ray Defendant(s): Kansas City Southern Railroad	Diesel Fuel & Exhaust/Benzene/ Asbestos	Negotiated Settlement 06/2021	MOT-19-002	2019-2021
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Michael D. Ruble and Brenda K. Ruble, his wife. Defendant(s): Rust-Oleum Corporation; RPM International; Inc., Zinsser Company, Inc., individually and as successor-in –interest to New Parks, a New Jersey corporation; Zinsser Company, Inc., d/b/a New Parks, a division of Zinsser Company, Inc., a New Jersey corporation; New Parks, a division of Zinsser Company, Inc., a New Jersey corporation; E. I. DuPont de Nemours and Company; Akzo Nobel, Inc., f/k/a Akzo America, Inc., individually and as successor-in-interest to Akzo Nobel Functional Chemicals, LLC and Akzo Nobel Chemicals, Inc., a Delaware corporation; Akzo Nobel Functional Chemicals, LLC; Akzo Nobel Chemicals, Inc.; Bayer Corporation; Bayer CropScience; Monsanto Company; The Early Construction Company; Advansix, Inc.; Altiva Petrochemicals, LLC; Brenntag Great Lakes, LLC; Brenntag Great Lakes, LLC: Brenntag Mid-South, Inc.; Citgo Petroleum Corporation; Exxon Mobil Corporation; FBC Chemical Corporation; Matriz Chemical, LLC; Nexeo Solutions, LLC; the Yenkin-Majestic Paint Corporation; Special Materials Company; and Univar Solutions, Inc., individually and as successor-by-merger to Nexeo Solutions, LLC, a Delaware corporation. In the Circuit Court of Cabell County, West Virginia (Supported Plaintiffs)	Exposure to Chemicals	On-Going	HAR-19-001 Case No. 19-C-127	2019-Present
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Mark Ady, Administrator of the Estate of Glenn R. Ady, Deceased Defendant(s): Shell Chemical LP, a Delaware limited partnership, d/b/a Shell Oil Company, et al. In the Circuit Court of Marshall County, West Virginia (Supported Plaintiff)	Formaldehyde Exposure	Negotiated Settlement 2019	HAR-19-003 Case No. 14-C-51K	2019
Weitz & Luxenberg P.C. Ms. Robin Greenwald Mr. Jerry Kristoff 700 Broadway	Plaintiff(s): Robert Dickey, Larry Domina, Royce Janzen, Yolanda Mendoza, Frank Pollard, John Sanders, & Frank Tanner	Exposure to Roundup Deposed 11/5 & 6/2019	Negotiated Settlement 06/2020	WL-19-001 Case No. 3:16-cv-05658-	2019-2020

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
New York, NY 10003 Levin Papantonio Thomas Mitchell Rafferty & Proctor, P.A. 316 South Baylen Street Pensacola, FL 32502	Defendant(s): Monsanto Company United States District Court, Northern District of California (Supported Plaintiffs)	Daubert Motion filed on 11/26/2019 – Decision moved to Local Federal Courts – Never Ruled On.		VC MDL No. 2741	
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Lee Roy Rodgers Defendant(s): Chevron Mining, Inc., Successor by Merger of Molycorp, Inc. & Union Oil Company of California and Unocal Corporation; The B'Laster Corporation, BP Corporation North America, Inc.; and the Henkel Corporation. In Court of Common Pleas, Washington County, PA. (Supported Plaintiff)	Thorium, Uranium, and Benzene Exposures	Negotiated Settlement 02/2020	HAR-19-004 Case No.: 2016-1836	2019-2020
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Mary Kay Virden, individually and as Executrix of the Estate of Charles E. Virden, deceased. Defendant(s): Covestro, LLC, as successor-in-interest to BayerMaterial Science, LLC a wholly owned affiliate of Bayer Corporation, which was formerly known as Miles, Inc., successor-in-interest to Mobay Corporation and Bayer U.S.A, a Pennsylvania limited liability company; Ashland LLC, a Kentucky limited liability company; Avantor, Inc., f/k/a Avantor Performance Materials d/b/a and successor to Mallinckrodt Baker, Inc., J.T. Baker, Inc., J.T. Baker Chemical Company, and VWR Corporation, a Delaware corporation; BP Amoco Chemical Company, as successor-in-interest to BP Chemicals, Inc., a Delaware Corporation; BP Products North America, Inc., successor-in-interest to BP Exploration & Oil, Inc., d/b/a BP Oil Company, a Maryland Corporation; Celanese Corporation, Successor-in Interest to Celanese AG, Hoechst Celanese Corporation and Celanese Chemicals, a Delaware Corporation; Chevron U.S.A., Inc., as successor-in-interest by merger to Union Oil Company of California and as successor-in-interest to UNOCAL Corp., a California Corporation; Exxon Mobil Corporation, a Delaware Corporation; Hess Corporation, f/k/a Hess Oil and Chemical Corporation, a New York corporation; Hexion Inc., formerly known as Momentive Specialty Chemicals, Inc., Successor-in-Interest to Hexion Specialty Chemicals, Inc., a Bordon Chemical, Inc., and Borden, Inc., a New Jersey corporation; Shell Chemical, LP, d/b/a Shell Oil Company, a Delaware limited partnership; Sunoco (R&M), LLC, successor-in-interest to Sun Company, Inc. (R&M), a Pennsylvania limited liability company; Tauber Oil Company, a Texas Corporation; Texaco, Inc., a Delaware corporation; Thermo Fisher	Exposure to Benzene and Benzene-Containing Chemicals	On-Going	HAR-19-005 Case No.: 19-C-252 C	2019-Present

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Scientific Inc., a successor-by-merger to Fisher Scientific International, Inc. successor to and f/k/a Fischer Scientific Company, a Delaware, Corporation; United States Steel Corporation, successor-in-interest to USX Corporation, USS chemicals Division, a Delaware Corporation; Valero Refining-Texas, L.P., as successor-in-interest by acquisition to Basis Petroleum, Inc., f/k/a Phibro Energy USA, Inc., a Delaware limited partnership. In the Circuit Court of Marshall County, West Virginia (Supported Plaintiff)				
J. Robert Black Black Law, PC 3701 Kirby Dr., Suite 101 Houston, TX 77098	Plaintiff(s): Aaron Augustine Defendant(s): DeBusk Services Group and Lubrizol. In the United States District Court Southern District of Texas Houston Division (Supported Plaintiff)	Chemical Burns to Feet and Ankles – Acrylonitrile Exposure	Negotiated Settlement 03/2020	BLA-19-003 Case No.: 4:19-cv-02157	2019-2020
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Charles E. Caton, Jr., aka Charles Caton Defendant(s): CSX Transportation, Inc. (CSXT); c/o CT Corporation System Statutory Agent, 4400 Easton Commons Way, Suite 125, Columbus, OH 43219; and Consolidated Rail Corporation (CONRAIL); 1717 Arch Street, Suite 1310, Philadelphia, PA 19103-2844; and American Premier Underwriters, Inc. (APU), Individually and as Successor-in-interest to The Penn Central Transportation Company, c/o CT Corporation System Statutory Agent, 4400 Easton Commons Way, Suite 125, Columbus, OH 43219 Court of Common Pleas of Hamilton County, Ohio (Supported Plaintiffs)	Diesel Fuel & Exhaust/Benzene/ Asbestos	Negotiated Settlement 03/2020	MOT-19-003 Case No.: A1903216	2019-2020
Weitz & Luxenberg P.C. Ms. Robin Greenwald Mr. Jerry Kristoff 700 Broadway New York, NY 10003. Levin Papantonio Thomas Mitchell Rafferty & Proctor, P.A. 316 South Baylen Street Pensacola, FL 32502	Plaintiff(s): Timothy Kane et al. (Crabtree, Edwin; Dela Cruz, Thomas; Dyer, Angela; Haynes, Rosita; and Ramirez, Ron). Defendant(s): Monsanto Company In the Circuit Court of the City of St. Louis, State of Missouri. (Supported Plaintiffs)	Exposure to Roundup Deposed 12/3 & 4/2019	Negotiated Settlement 06/2020	WL-19-002 Case No. 1622-CC10172	2019-2020
Weitz & Luxenberg P.C. Ms. Robin Greenwald Mr. Jerry Kristoff 700 Broadway New York, NY 10003.	Plaintiff(s): Leroy Seitz, et al. (Cannon, Mario; Jenkins, Larry; Pinnon, Jerry; and Sorich, Scott). Defendant(s): Monsanto Company In the Circuit Court of the City of St. Louis, State of Missouri. (Supported Plaintiffs)	Exposure to Roundup Deposed 1/15 & 16/2020	Negotiated Settlement 06/2020	WL-19-003 Case No. 1722-CC11325	2019-2020

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Levin Papantonio Thomas Mitchell Rafferty & Proctor, P.A. 316 South Baylen Street Pensacola, FL 32502					
Nadina Beach Lundy Soileau & South, LLP 501 Broad Street Lake Charles, Louisiana 70601	Plaintiff(s): LaTwon Whitby Defendant(s): Monsanto In the Circuit Court of the County of St. Louis, State of Missouri. (Supported Plaintiff)	Exposure to Roundup Deposed on 2/7/2020	Negotiated Settlement 06/2020	LUN-19-001 Case No.: 19SL-CC04020	2019-2020
Mr. Christopher Heavens 2438 Kanawha Blvd. East Charleston, WV 25311	Plaintiff(s): Justin Butcher and Jennifer Butcher Defendant(s): Halliburton Energy Services, Inc., a Delaware Corporation, Antero Resources Corporation, a Delaware Corporation, and Safety Management Systems, LLC, a Louisiana Corporation. In the United States District Court for the Northern District of West Virginia, Clarksburg. (Supported Plaintiff)	Work-related Amputation/Injury	On-going	HEA-19-001 Civil Action No. 1:20cv74 (Kleeh)	2019-Present
Mr. John E. Tomlinson Beasley, Allen, Crow, Methvin, Portis & Miles, P.C. 218 Commerce Street Montgomery, AL 36104	Plaintiff(s): Hollis D. Graham and Shirley Graham Defendant(s): 3M Company; American Offset Printing Ink; Anchor/Lith-Kem-Ko, Incorporated, a Subsidiary of FugiFilm Hunt Chemicals USA, Incorporated; FugiFilm Hunt Chemicals USA, Incorporated, d/b/a and Parent and Successor to Anchor/Lith-Kem-Ko, Incorporated; Day International, Inc.; Deleet Merchandising Corp.; Flint Group US, LLC; Fujifilm Hunt Chemicals USA, Inc.; Printer Service d/b/a Prisco; Rogersol, Inc., Rycoline Products, Inc., a Division of Sun Chemical Commercial Group a/k/a Rycoline Products, LLC and Successor to Rogersol, Inc.; Sun Chemical Corporation, Individually and a Parent and Successor to Rycoline Products, LLC, a/k/a Rycoline Products, Inc. and Successor to Rogersol, Inc.; Varn International, d/b/a Varn Products Company; Day International, Inc., Individually and as Successor to and d/b/a Varn Products Company. In the United States District Court, Northern District of Alabama, Southern Division (Supported Plaintiffs)	Exposure to Printing Products	Negotiated Settlement 12/2020	BEA-20-001 Case #: 2:18-cv-1362-RDP.	2020
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Frederick R. Eastman and Janet L. Eastman, his wife. Defendant(s): Sunoco, Inc.; Texaco, Inc.; Exxon Mobil Corp.; BP Amoco Chemical Company; BP Products North America, Inc.; 3-M Company; CRC Industries, Inc., Advanced Auto Parts, Inc. The B'Laster Corporation; Radiator Specialty	Exposure to Chemicals	On-going	HAR-20-001	2020-Present

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Company; United States Steel Corporation; Safety-Kleen Systems, Inc., Kano Laboratories; Valvoline, Inc.; Rust-Oleum Corporation; The Testor Corp.; E.I. DuPont de Nemours & Company; The Sherwin-Williams Company; The Valspar Corporation; Autozone, Inc.; Pennzoil-Quaker State Company; W.M Barr & Company, Inc.; PPG Industries, Inc.; AGS Company Solutions, LLC; Sig Manufacturing Company, Inc.; Automotive Systems Warehouse, Inc.; Niteo Products, LLC; Illinois Tool Works, Inc.; Chase Products Company; Wilson Imperial Company; Zep, Inc. In the Court of Common Pleas of Allegheny County, Pennsylvania (Supported Plaintiffs)				
Mr. Kristofer Cormany Cormany Law, PLLC P.O. Box 11827 206 Capitol Street Charleston, WV 25339	Plaintiff(s): Lori Harrison, Administratrix of the Estate of Sarah Cain, Deceased. Defendant(s): Go-Mart, Inc., a West Virginia Corporation, and Heater Oil Company, Inc., a West Virginia Corporation. In the Circuit Court of Putnam County, West Virginia (Supported Plaintiff)	Exposure to Chemicals in Go-Mart Bathroom – Death of Women and Fetus	Negotiated Settlement February 2021	COR-20-001 Civil Action No.: 19-C-115	2020-2021
J. Robert Black Black Law, PC 3701 Kirby Dr., Suite 101 Houston, TX 77098	Plaintiff(s): James Crabtrey and Brenda Crabtrey Defendant(s): Atlantic Richfield Company; Bayer Corporation; Berryman Products, Inc.; Celanese Corporation; Chevron USA, Inc.; Covestro, LLC; Huntsman International, LLC; Ineos Styrolution America, LLC; Nova Chemicals, Inc.; Occidental Chemical Corporation; Radiator Specialty Company; Schneider Electric Systems USA, Inc.; Shell Oil Company; Total Petrochemicals & Refining USA, Inc.; Union Oil Company of California; United States Steel Corporation In the District Court Harris County, Texas (Supported Plaintiffs)	Chemical Exposure	On-Going	BLA-20-001 Cause No. 2020-05009 – Court 189	2020-Present
Mr. David P. Matthews Matthews & Associates 2905 Sackett Street Houston, TX 77098	Plaintiff(s): Randall Dean Seidl et al. Defendant(s): Monsanto Co. United States District Court, Northern District of California & In the Circuit Court of Jefferson County State of Missouri. (Supported Plaintiffs)	Exposure to Roundup	Non-resolved cases moved to Frazer, PLC	MAT-20-001 Case No.: 3:17-cv-00519 MDL No. 2741 & Cause No.: 20JE-CO00709	2020-2021

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
William R. Sutton Beasley Allen Law Firm 218 Commerce St. Montgomery, AL 36104	Plaintiff(s): Randall Dean Seidl Defendant(s): Monsanto Co. United States District Court, Northern District of California (Supported Plaintiff)	Exposure to Roundup Deposed 3/2/2021	On-Going	BEA-20-2002 Case No.: 3:17-cv-00519 MDL No. 2741	2020-Present
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Cynthia Minnis, Personal Representative of the Estate of Porter K. Minnis, Deceased. Defendant(s): BNSF Railway Company, Individually and as Successor-in-Interest to The Burlington Northern, Inc., Burlington Northern & Santa Fe Railway Company, and Atchison, Topeka and Santa Fe Railway Company. In the Circuit Court of Linn County, State of Missouri (Supported Plaintiff)	Exposure to Diesel Fuel, Diesel Exhaust, Benzene, & Asbestos	On-Going	MOT-19-006 Civil Action No.: 19LI-CC00036	2021-Present
Mr. Wesley A. Bowden, Esq. Levin Papantonio Thomas Mitchell Rafferty & Proctor, P.A. 316 South Baylen Street Pensacola, FL 32502	In RE: Aqueous Film-Forming Foams Products Liability Litigation In the United States District Court for the District of South Carolina Charleston Division (Supported Plaintiff(s))	PFASs Expert Support	On-Going	LEV-21-002 MDL No.: 2:18-mn-2873-RMG	2021-Present
Mr. Wesley A. Bowden, Esq. Levin Papantonio Thomas Mitchell Rafferty & Proctor, P.A. 316 South Baylen Street Pensacola, FL 32502	Plaintiff(s): Middlesex Water Company, New Jersey. Defendant(s): 3M Company. United States District Court for the District of New Jersey (Supported Plaintiff)	Evaluation of Treatment Methods and Costs for Removals of PFASs	On-Going	LEV-21-003 Case No.: 2:18-cv-15366	2021-Present
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Teddy A. Kemp and Judy L. Kemp, his wife. Defendant(s): Covestro, LLC, as successor-in-interest to BayerMaterial Science, LLC a wholly owned affiliate of Bayer Corporation, which was formerly known as Miles, Inc., successor-in-interest to Mobay Corporation and Bayer U.S.A, a Pennsylvania limited liability company; Axial Corporation, as successor-in-interest to PPG Industries, Inc., a Delaware Corporation; Ashland LLC, a Kentucky limited liability company; BP Amoco Chemical Company, as successor-in-interest to BP Chemicals, Inc., a Delaware Corporation; BP Products North America, Inc., successor-in-interest to BP Exploration & Oil, Inc., d/b/a BP Oil Company, a Maryland Corporation; Chevron U.S.A., Inc., as successor-in-interest by merger to Union Oil Company of California and as successor-in-interest to UNOCAL Corp., a California Corporation; Citgo Petroleum Corp., a Delaware Corporation; Conoco-Phillips Company, as successor by merger to Conoco, Inc. and f/k/a Phillips Petroleum Company, a Delaware Corporation; Exxon Mobil Corporation, a Delaware Corporation; Recochem, Inc., as successor-in-interest to	Exposure to Benzene	Negotiated Settlement 04/12/2001	HAR-20-004 Civil Action No.: 19-C-113C	2020-2021

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
	Record Chemical Company, a Delaware Corporation; Shell Chemical, LP, d/b/a Shell Oil Company, a Delaware limited partnership; Sunoco (R&M), LLC, successor-in-interest to Sun Company, Inc. (R&M), a Pennsylvania limited liability company; Tauber Oil Company, a Texas Corporation; Union Oil Company of California, individually and as successor-in-interest by merger to UNOCAL Corp., a California Corporation; United States Steel Corporation, successor-in-interest to USX Corporation, USS chemicals Division, a Delaware Corporation; Valero Refining-Texas, L.P., as successor-in-interest by acquisition to Basis Petroleum, Inc., f/k/a Phibro Energy USA, Inc., a Delaware limited partnership; P&B Steel Erectors, Inc., a West Virginia Corporation; and Sistersville Tank Works, Inc., individually and successor-in-interest to Tyler County Tank Works, Inc. a West Virginia Corporation. In the Circuit Court of Marshall County, West Virginia (Supported Plaintiffs)				
R. Dean Hartley Hartley Law Group, PLLC The Wagner Building 2001 Main Street, Suite 600 Wheeling, WV 26003	Plaintiff(s): Gregory S. Gwinn and Kimberly Ann Gwinn, his wife Defendant(s): Axalta Coating Systems, LLC, a Delaware LLC; Beckley Welding Supply, Inc., a West Virginia Corporation; Crest Industries, Inc., a Michigan Corporation; E.I. DuPont de Nemours and Company, a Delaware Corporation; Fleetwood Products, Inc.; a New Jersey Corporation; Genuine Parts Company, d/b/a NAPA Auto Parts, a Georgia Corporation; Grow Automotive, a foreign entity; International Autobody Marketing Group (IAMG), an Arizona Corporation; Mountain Marketing, Inc., a West Virginia Corporation; PPG Industries, Inc., a Pennsylvania Corporation; Refinishing Material Specialties, Inc. d/b/a RMS Pro Finishes, Inc., individually and as successor-in-interest to Warren's Auto Parts, Inc., d/b/a Auto Body & Paint Supply, a West Virginia Corporation; Safety-Kleen Systems, Inc., a Wisconsin Corporation; The Sherwin-Williams Company (Martin Senour Automotive Finishes Division), an Ohio Corporation; Transtar Autobody Technologies, Inc., an Ohio Corporation; U-Pop US, Inc., a foreign entity; The Valspar Corporation, a Delaware Corporation; Warren's Auto Parts, Inc., d/b/a Auto Body & Paint Supply, a West Virginia Corporation; and William Farruggia, d/b/a B&L Distributors, a sole proprietorship. In the Circuit Court of Kanawha County, West Virginia. Honorable Judge Louis H. "Duke" Bloom (Supported Plaintiffs)	Exposure Surfactants and Surfactant Ingredients	On-going Deposed 4/13/2021, 4/14/2021 and 6/2/2021	HAR-20-005 Case No.: 17-C-622	2020-Present

ATTORNEY/LAW FIRM	CASE (Plaintiff(s) and Defendant(s) & Role	SUBJECT	DECISION	Project #/Case #	TIMEFRAME
Mr. Christopher Wiest Chris Wiest, Attorney at Law, PLLC 25 Town Center Blvd, Ste. 104 Crestview Hills, KY 41017	Plaintiff(s): Ridgeway Properties, LLC d/b/a Beans Café & Bakery and Commonwealth of Kentucky, ex re. Attorney General Daniel Cameron Defendant(s): Hon. Andrew Beshear, Governor, Commonwealth of Kentucky, et al. Commonwealth of Kentucky Boone County Court, Division 1 (Supported Plaintiffs)	COVID – Lockdowns, Masks and PPE	Trial Testimony on May 17, 2021 Bench Trial Decision in Favor of Plaintiffs on 6/8/2021	WEI-21-001 Case No.: 20-CI-00678	2021-2021
Mr. Seldon Jeff Childers Childers Law, LLC 2135 NW 40th Terrace, Suite B Gainesville, Florida 32605	Plaintiff: Justin Green Defendant(s): Alachua County, a political subdivision of the State of Florida In the Circuit Court of the Eighth Judicial Circuit in and for Alachua County, Florida & First District Court of Appeal State of Florida (Supported Plaintiff)	COVID – Lockdowns, Masks and PPE	Disclosed 4/21/2021 Appellant Decision in Favor of Plaintiffs for Reversal and Remanding 6/11/2021	WEI-21-001 Case No.: 2020-CA-1249	2021-2021
Mr. Patrick D. McMurtray Frazer PLC Burton Hills II 30 Burton Hills Blvd., Suite 450 Nashville, TN 37215	Plaintiff(s): Dolores Verdier, et al. Defendant(s): Monsanto Company, et al. In the Circuit Court of Jefferson County State of Missouri. (Supported Plaintiffs)	Exposure to Roundup	On-Going	FRA-21-001 Cause No.: 20JE-CO00709	2021-Present
Mr. John (Rett) Guerry III Motley Rice LLC 28 Brigeside Blvd. Mt. Pleasant, SC 29464	Plaintiff(s): Carolyn L. Robinson, as Executrix of the Estate of Jesse Irvin Robinson, Deceased and Wrongful Death Beneficiary and Surviving Spouse. Defendant(s): Illinois Central Railway Company. In the Circuit Court of the 19th Judicial District of Jackson County, Mississippi. (Supporting Plaintiff)	Exposure to Diesel Fuel, Diesel Exhaust, Herbicide, Solvents, & Asbestos	On-Going	MOT-21-001 Civic Action: 21-28(3)	2021-Present

EXHIBIT iii

AIHA™

HEALTHIER WORKPLACES | A HEALTHIER WORLD

Reducing the Risk of COVID-19 Using Engineering Controls

Guidance Document

aiha.org

Version 4 September 9, 2020

Sponsored by the AIHA® Indoor Environmental Quality Committee

Early case reports and epidemiological studies of groups where SARS-CoV-2 has led to outbreaks of COVID-19 indicates that the primary means of disease transmission is the indoor spread of exhaled droplet aerosols. Armed with this knowledge, industrial hygiene professionals may limit SARS-CoV-2 transmission using the hierarchy of controls. Engineering controls that can keep infectious aerosols at very low levels indoors offer the greatest promise to protect non-healthcare workers and other vulnerable populations as we reopen our businesses and workplaces.

Relying upon individuals to maintain social distancing, perform perpetual hand washing, and, when available, wear the lowest form of personal protective equipment (PPE) on the market can only achieve so much in preventing the spread of COVID-19. And because infected people transmitting the disease can be asymptomatic or presymptomatic, it is impractical to "eliminate" all sources of infection. With this in mind, the industrial hygiene profession has long recognized that engineered solutions to reduce exposure to hazardous agents offer much greater protection than PPE or administrative controls in most workplace settings. (NIOSH) (See Figure 1)

Many employers and the public incorrectly assume that wearing face coverings or a respirator is the only way to reduce their risk of exposure. Invariably this is not the case—the reality is that wearing a respirator properly every day, all day, is uncomfortable and rarely done properly. Engineering controls have historically proven to be more reliable because they are less prone to human error.

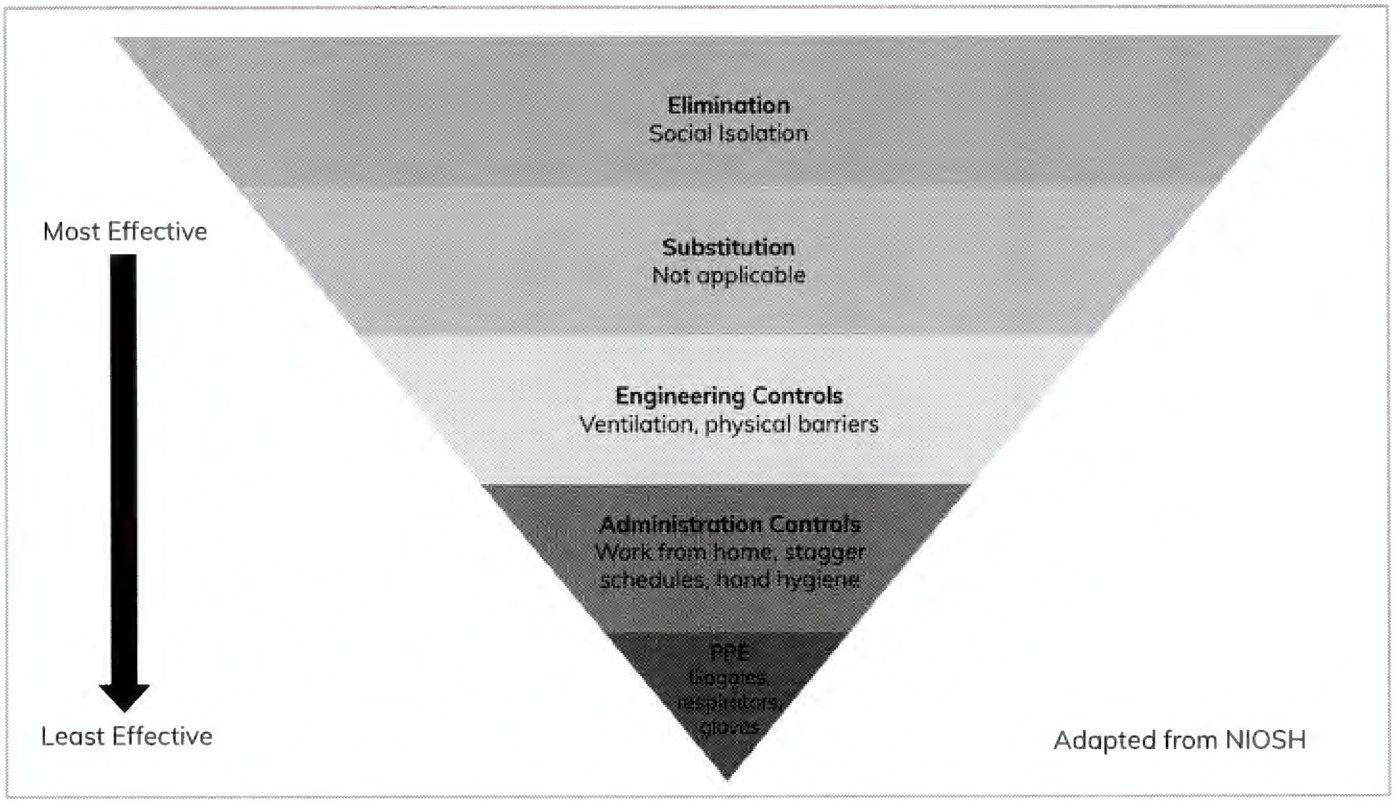


Figure 1: Applying the Hierarchy of Controls for COVID-19.

Accordingly, while federal and state OSHA plans require employers to ensure workers can use a selected respirator, OSHA also requires employers to consider feasible engineering and administrative options before resorting to their use or that of other PPE. Employers should select off-the-shelf, reliable, and effective engineering controls to reduce the risk of workplace disease spread.

The cost of PPE is also higher than most employers realize. Because OSHA requires medical evaluation, fit testing, and training, respiratory PPE is not a recommended long-term solution to prevent disease transmission outside of healthcare settings. Respiratory PPE is best used for short-term protection until engineering controls can be implemented. Costs to implement engineered solutions in a workplace can vary, depending upon the size of the facility and number of occupants, including employees and transient customers. Once engineering controls are installed, concerns of shortages and supply interruptions that have plagued PPE supplies are not likely to be an issue.

The American Industrial Hygiene Association (AIHA) and its volunteer committees of industrial hygienists recommend the use of engineering controls in all indoor workplaces, even those outside of the healthcare industry, to reduce the spread of COVID-19. The broad category of engineering controls that may be effective against the SARS-CoV-2 virus includes the following:

- Physical barriers, enclosures, and guards
- Automatic door openers and sensors
- Local exhaust ventilation
- Enhanced filtration to capture infectious aerosols
- Devices that inactivate or "kill" infectious organisms
- Dilution ventilation and increasing outside air delivery

Dilution Ventilation and COVID-19

Exemplifying one kind of engineered control, ASHRAE, a professional association of engineers, has issued position statements maintaining that changes to building and HVAC operation can reduce the airborne concentration of SARS-CoV-2 and the risk of it spreading through indoor air.

Increasing the number of effective air changes per hour—essentially, increasing the amount of "clean" or outdoor air delivered to the room—lowers the occupant's level of exposure to airborne viruses and therefore his or her relative risk of contracting the disease. Diluting indoor airborne virus concentrations can lower the risk of contracting the disease for the same reason that outdoor environments pose less risk of disease transmission.

This suggests that the risk of contracting COVID-19 can be significantly reduced by increasing indoor dilution ventilation rates and improving room air mixing—a principle recommended by the CDC and healthcare licensing bodies for hospitals and infectious disease wards. Indoor environments pose a much greater risk of exposure and spread of disease than outdoor environments. Outdoor environments offer "infinite dilution" of infectious aerosols, which strongly suggests that the risk of contracting COVID-19 can be significantly reduced by increasing dilution ventilation rates and improving room air mixing. To reduce the risk of disease transmission, maintain aerosol concentrations at very low levels, keep occupancy density low, and maintain physical distance. Accordingly, fundamental principles and equipment to capture and dilute aerosols can be applied to non-industrial workplaces to achieve more effective and reliable control of SARS-CoV-2 than face coverings and social distancing.

Effectively increasing the number of air changes in a room or building can be achieved by one or more of the following approaches. Using stand-

alone "off-the-shelf" HEPA filtered air cleaners , installing enhanced filtration in central HVAC systems, and increasing the volume of outside air introduction are practical and immediate measures that can be implemented by building operators and employers.

Properly selected and installed, standalone single-space HEPA filtration units that are ceiling mounted or portable can effectively reduce infectious aerosol concentrations in a single space room or zone, such as a classroom, elevator, lobby, or office area. While in-room filtering units cannot eliminate all risk of disease transmission because many factors besides virus aerosol concentration contribute to the issue, the reduced concentration and residence time of infectious aerosols can substantially decrease an individual's likelihood of inhaling an infectious dose. (ASHRAE Position Statement on Infectious Aerosols, 2020)

Choosing and Implementing Engineered Controls

Compared to solutions relying mostly or exclusively on PPE, engineered solutions removes the onus from individuals and their personal habits or attentiveness. Machines do not get tired, sloppy, or distracted.

However, when selecting engineering controls, such as increasing the number of air changes per hour (ACH), the minimum level of protection offered by the new control should exceed the protection offered by PPE alone. In Figure 2, the expected relative risk reduction offered by an N95 respirator is 90 percent, therefore only engineering controls that offer greater than 90 percent relative risk reduction should be considered. In this instance, engineering controls that offer fewer than 4.5 effective air changes per hour are no better than commercially available respiratory protection.

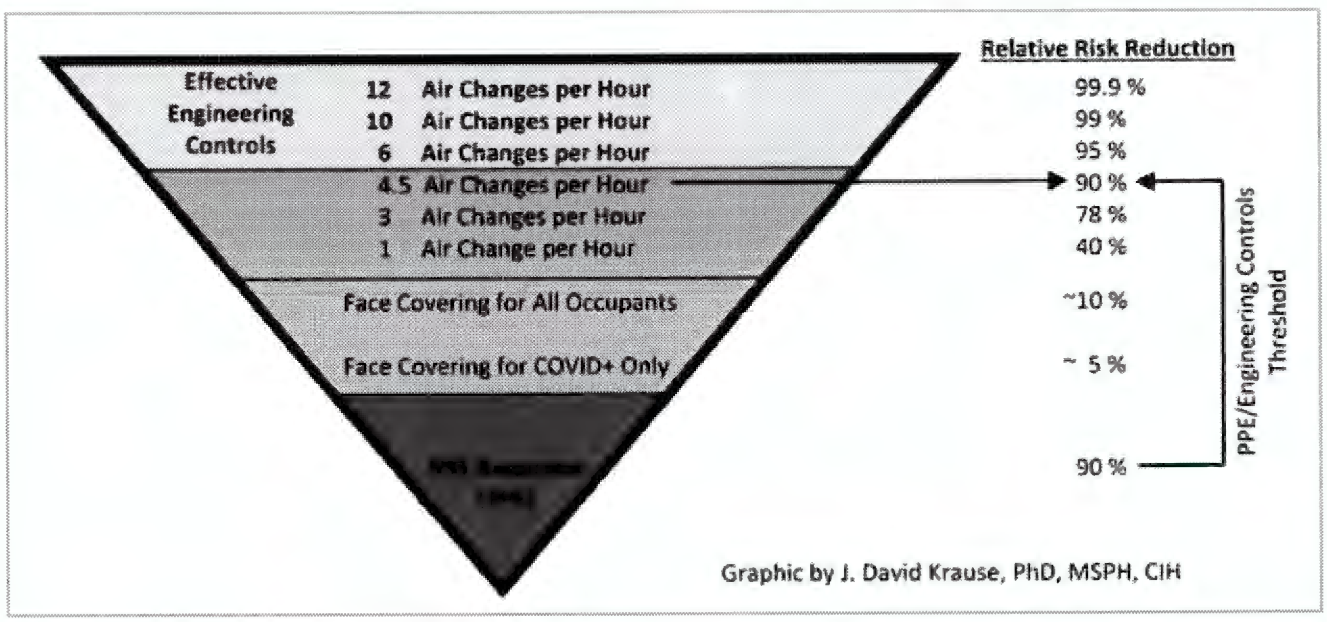


Figure 2*

*To learn how the relative risk reduction estimates were derived for Figure 2, download the SUPPLEMENT for Reducing the Risk of COVID-19 using Engineering Controls.

In hospitals and other indoor environments where infectious people are likely present, delivering between 6 and 12 air changes per hour of outside or clean air significantly reduces the spread of infectious airborne diseases. (See Figure 3) In non-healthcare facilities where occupant density cannot be limited to fewer than 1 person per ~30 ft^2 (i.e. 6-foot radius), or there is likelihood that infected persons are present, delivering higher air change rates than 6 ACH may be necessary.

Additional factors must be considered for site-specific engineering controls, such as in-room air mixing, the number of occupants per square foot of office space, and the air flow dynamics already in place. A knowledgeable mechanical engineer and industrial hygienist familiar with ventilation controls and infection prevention should be consulted when selecting, installing, and evaluating engineering controls for a workplace.

In most office buildings and small retail settings, using a computational fluid dynamics (CFD) model is not necessary to achieve intended effects. However, in complex buildings with existing mechanical and exhaust systems, CFD modeling may be needed to design and implement a robust and reliable system.

Standalone high efficiency particulate arrestance (HEPA) air filtering devices (AFDs) can be used to supplement outdoor air ventilation supplied through HVAC systems in order to achieve equivalent air exchange rates (AERs) capable of significantly reducing infectious aerosol concentrations in workplaces and offices. The CDC's *Guidelines for Environmental Infection Control in Health-Care Facilities*, published in 2003 recommends using recirculation HEPA filters to "increase the equivalent room air exchanges." The guidelines further suggest that "recirculating devices with HEPA filters may have potential uses in existing facilities as interim, supplemental environmen-

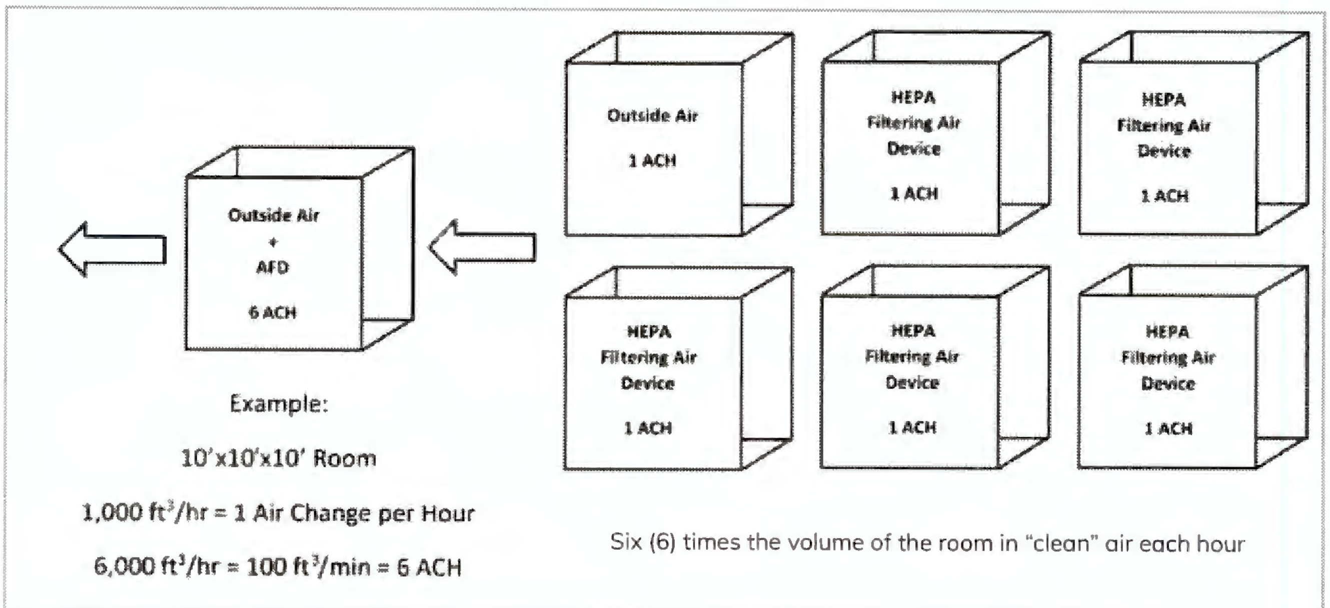


Figure 3

tal controls to meet requirements for the control of airborne infectious agents." (https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#tableb1)

But HEPA rated filters are not necessary to achieve meaningful reductions in airborne concentrations. Enhanced filtration using filters with MERV (minimum efficiency reporting value) ratings between 13 and 15 can also be used, but higher flow rates may be necessary to achieve similar effects. Installing improved filtration (MERV 13 or higher) in central HVAC systems can serve to supplement air change rates by further reducing infectious aerosol concentrations in recirculated air. Increasing filtration of an HVAC system should be evaluated by a mechanical engineer to ensure the fan can handle the increased pressure load and that air does not bypass the filters. Increased maintenance and filter changes will likely be needed.

While ultraviolet germicidal irradiation (UVGI) and other technologies to inactivate, but not capture, viruses may be capable of reducing airborne concentrations of infectious aerosols, many factors can reduce their effectiveness without being readily recognized by users. Such technologies and equipment can often require significant modification to existing mechanical equipment and ongoing service.

Engineering Precautions

When increasing outside air delivery through HVAC systems, engineers must take precautions to avoid exceeding the mechanical system's design and operational capabilities. Too much outdoor air can introduce high levels of humidity, causing mold and bacterial growth within the HVAC system, its ducts, and the occupied areas of the building. When outdoor air pollution from wildfires, nearby excavation, or demolition activities threatens the area, outside air dampers may have to be temporarily closed.

When installing AFDs it is important to avoid air flows that interfere with existing HVAC systems, or that directs potentially contaminated air into a clean area. This often requires the expertise of an engineer, industrial hygienist, or experienced contractor to properly site each device.

Ongoing maintenance and cleaning of AFDs, including changing pre-filters and HEPA filters, is necessary to ensure effective operation. Precautions must be taken to prevent worker exposures to accumulated infectious viruses on the filters or the AFD exterior during filter changes and maintenance. PPE recommended for maintenance activities such as filter changes and periodic cleaning include goggles, gloves, apron, and N95 respirator. This should be performed when unprotected individuals are not nearby.

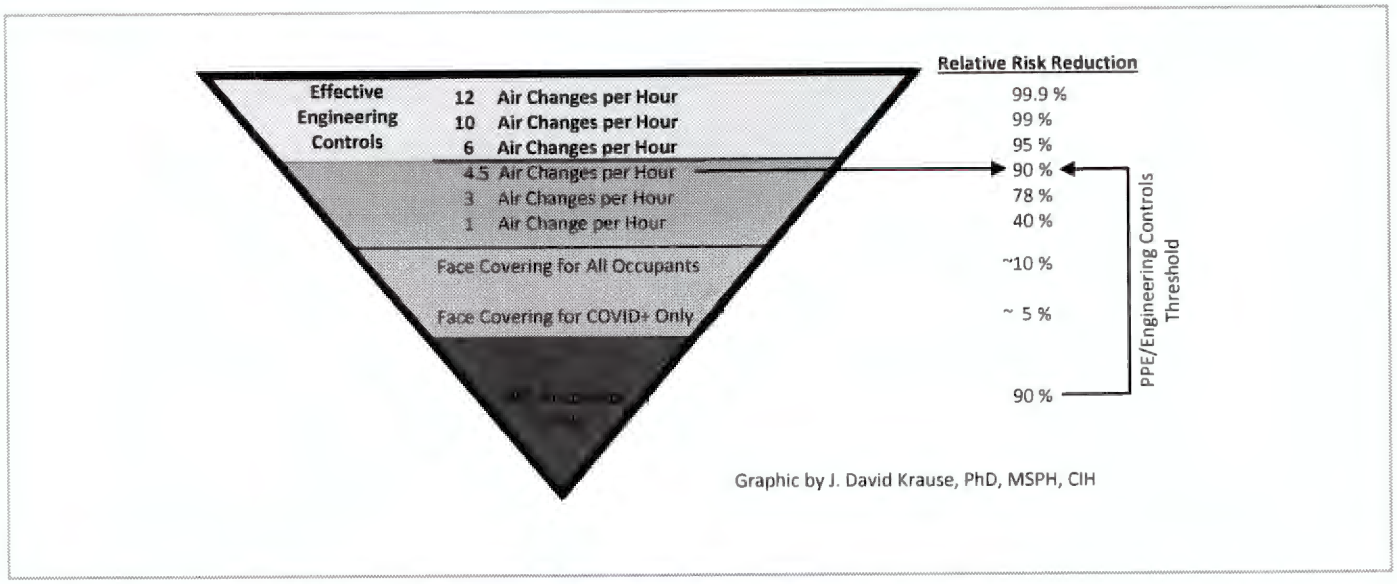
Any modifications made to central HVAC systems, either to accommodate a new use of the space, changes in occupant density, or to improve filtration should be specified and reviewed by a mechanical engineer.

Conclusions

As the nation moves to restart the economy and in-person education, we must seriously consider and adopt effective engineering controls in public buildings in order to protect the health of employees and occupant. Using "off-the-shelf" technologies, equipment, and time-tested methods to control infectious aerosols is the most reliable way to reduce the risk of disease spread. Relying upon control measures that only offer marginal protection against the spread of disease could extend this pandemic until a vaccine is developed, produced, and distributed. Scientifically proven methods to control the spread of airborne diseases that include enhanced ventilation with outdoor air, and high efficiency filtration, have not been widely implemented outside of healthcare facilities.

Industrial hygienists and mechanical engineers can design, install, and evaluate engineering controls that are capable of keeping infectious aerosols at very low levels indoors and offer more reliable protection. Together, we can help reduce the risk of disease transmission among workers and members of the community in properly designed and maintained buildings through the use of engineering controls.

Appendix



Derivation of estimated relative risk reduction offered by different control measures described in Figure 2

This supplement is provided to explain how estimates of relative risk reduction were derived for face coverings and engineering controls in Figure 2 of the AIHA guidance document Reducing the Risk of COVID-19 using Engineering Controls, Version 1, August 11, 2020. Citations of published studies and available CDC guidance are provided by reference and the considerations made by authors and contributors to the guideline are discussed.

Rengasamy et al reported that fabric materials commonly used to construct face coverings may only provide marginal protection against particles in the size range of virus-containing particles in exhaled breath. Average penetration levels for the three different cloth masks were between 74% and 90% (meaning they captured between 10% and 26% of aerosols), while N95 filter media controls showed penetration of only 0.12% at 5.5 cm/sec face velocity.[1] The average penetration levels for three different models of towels and scarves ranged from 60–66% and 73–89% respectively. "The results obtained in the study showed that cloth masks and other fabric materials had 40–90% instantaneous penetration levels when challenged with polydisperse NaCl aerosols. Similarly, varying levels of penetration (9–98%) were obtained for different size monodisperse NaCl aerosol particles in the 20–1000 nm range." Two of the five surgical masks that were evaluated demonstrated 51–89% penetration levels against polydisperse aerosols.[1]

While not evaluated in this study, face seal leakage is known to further decrease the respiratory protection offered by fabric materials. Aerosol penetration for face masks made with loosely held fabric materials occurs in both directions (inhaled and exhaled). Due to their lose fitting nature and the leakage that

occurs even when a face mask is properly worn, a modifying factor of 25% was applied.

Finally, compliance with the proper wearing of face coverings when people generate the most aerosols (i.e. speaking, exercising, etc.) significantly impacts the anticipated risk reduction they can offer. Due to observed lapses in proper wearing of cloth face coverings (i.e. covering only the mouth or wearing them below the chin) and when people pull the mask down when speaking to someone, a modifying factor of 50% was applied. A face covering only worn half the time or covering only the mouth offers less risk reduction.

MacIntyre et al reported that laboratory tests showed the penetration of particles through cloth masks to be very high (97%) when compared to medical masks (44%) that were tested, and when compared to N95 3M model 9320 (<0.01%), and the 3M Vflex 9105 N95 (0.1%). In other words, the cloth masks tested in this study only captured 3% of the exhaled aerosols.[2]

This study also evaluated compliance of healthcare workers wearing cloth masks and medical masks. They found that healthcare workers complied only 56.5% of the time for cloth masks and 56.8% of the time for medical masks.[2]

The high levels of initial penetration reported in the studies cited above, ranging from 40-97% equates to capture efficiencies of 3-60%. The impact of typical leakage and frequent non-compliance with proper use and wear, is the basis for a generous estimate of 5-10% relative risk reduction for face masks and cloth face coverings. Studies do suggest that surgical and medical masks, when worn properly and with full compliance could offer greater protection, for both the wearer and for those nearby. However, their availability and proper use is not currently required and was not the basis for the relative risk reduction estimated for reusable facial coverings and masks.

This supplement is not intended to suggest that face coverings and masks not be used, but rather to objectively examine and recognize their contribution to risk reduction. In light of the limited level of relative risk reduction offered by face coverings and masks the AIHA has recommended engineering controls be used to reduce the risk of exposure in indoor environments, which is anticipated to reduce the transmission of disease, even in nonhealthcare settings.

Estimates of relative risk reduction presented in the figure above that can be offered by outside air ventilation and/or enhanced filtration (i.e. HEPA or MERV 17) were derived using the model presented below. Initial and ending concentrations of respirable aerosols were modeled at various air change rates in a room over a 30-minute period. Similarly, the steady state concentration of aerosols given equal source strength (i.e. virus-containing aerosols exhaled by a person) can be estimated using this model. The formula and its applicability to infectious disease control are described in detail in the CDC Guidelines for Environmental Infection Control in Health-Care Facilities (2003).[3]

$$t_2 - t_1 = -[\ln(C_2 / C_1) / (Q / V)] \times 60, \text{ with } t_1 = 0$$

where

t_1 = initial timepoint in minutes

t_2 = final timepoint in minutes

C_1 = initial concentration of contaminant

C_2 = final concentration of contaminant

$C_2 / C_1 = 1 - (\text{removal efficiency} / 100)$

Q = air flow rate in cubic feet/hour

V = room volume in cubic feet

Q / V = ACH

1. Rengasamy, S., Eimer, B., and Shaffer, R. E. Simple Respiratory Protection—Evaluation of the Filtration Performance of Cloth Masks and Common Fabric Materials Against 20–1000 nm Size Particles. Ann. Occup. Hyg., Vol. 54, No. 7, pp. 789–798, 2010
2. MacIntyre CR, Seale, H., Dung, , TC, et al. A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. BMJ Open 2015;5:e006577. doi:10.1136/bmjopen-2014-006577
3. CDC Guidelines for Environmental Infection Control in Health-Care Facilities (2003) https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#tableb1

AIHA is the association for scientists and professionals committed to preserving and ensuring occupational and environmental health and safety (OEHS) in the workplace and community. Founded in 1939, we support our members with our expertise, networks, comprehensive education programs and other products and services that help them maintain the highest professional and competency standards. More than half of AIHA's nearly 8,500 members are Certified Industrial Hygienists, and many hold other professional designations. AIHA serves as a resource for those employed across the public and private sectors, as well as to the communities in which they work.

EXHIBIT iv

Physics of Fluids ARTICLE scitation.org/journal/phf

Experimental investigation of indoor aerosol dispersion and accumulation in the context of COVID-19: Effects of masks and ventilation

Cite as: Phys. Fluids 33, 073315 (2021); doi: 10.1063/5.0057100
Submitted: 17 May 2021 · Accepted: 2 July 2021 ·
Published Online: 21 July 2021

View Online Export Citation CrossMark

Yash Shah, John W. Kurelek, Sean D. Peterson, and Serhiy Yarusevych[a]

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Note: This paper is part of the special topic, Flow and the Virus.

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ABSTRACT

The ongoing COVID-19 pandemic has highlighted the importance of aerosol dispersion in disease transmission in indoor environments. The present study experimentally investigates the dispersion and build-up of an exhaled aerosol modeled with polydisperse microscopic particles (approximately 1 μm mean diameter) by a seated manikin in a relatively large indoor environment. The aims are to offer quantitative insight into the effect of common face masks and ventilation/air purification, and to provide relevant experimental metrics for modeling and risk assessment. Measurements demonstrate that all tested masks provide protection in the immediate vicinity of the host primarily through the redirection and reduction of expiratory momentum. However, leakages are observed to result in notable decreases in mask efficiency relative to the ideal filtration efficiency of the mask material, even in the case of high-efficiency masks, such as the R95 or KN95. Tests conducted in the far field (2 m distance from the subject) capture significant aerosol build-up in the indoor space over a long duration (10 h). A quantitative measure of apparent exhalation filtration efficiency is provided based on experimental data assimilation to a simplified model. The results demonstrate that the apparent exhalation filtration efficiency is significantly lower than the ideal filtration efficiency of the mask material. Nevertheless, high-efficiency masks, such as the KN95, still offer substantially higher apparent filtration efficiencies (60% and 46% for R95 and KN95 masks, respectively) than the more commonly used cloth (10%) and surgical masks (12%), and therefore are still the recommended choice in mitigating airborne disease transmission indoors. The results also suggest that, while higher ventilation capacities are required to fully mitigate aerosol build-up, even relatively low air-change rates (2 h^{-1}) lead to lower aerosol build-up compared to the best performing mask in an unventilated space.

I. INTRODUCTION

Expiratory events, such as breathing, speaking, sneezing, or coughing, produce droplets, ranging in micrometers to millimeters in size, that serve as the primary pathway for the transmission of many infectious diseases, including coronavirus disease 2019 (COVID-19).[1–6] The ongoing COVID-19 pandemic underscored glaring gaps in our understanding of pathogen transmission required to effectively contain and prevent outbreaks, including, but not limited to, the development of reliable guidelines for safe social distancing,[1,2] usage of personal protective equipment (PPE),[7,8] and indoor ventilation.[3,9] The initial guidelines released in early 2020 by the World Health Organization and many national health agencies assumed that COVID-19 spreads primarily through large droplets that settle on surfaces within 1 to 2 m from the infected individuals. Although an intense scientific debate on the main transmission pathways of COVID-19 continues,[10,11] the mounting data on local outbreaks and relevant research[9,12,13] have prompted significant modifications to official guidelines, which now attribute the spread of COVID-19 to a wide range of droplet sizes, including both larger respiratory droplets and microscopic aerosols, produced during various expiratory events.[14–16]

Recent research has shown that smaller droplets and droplet nuclei containing significant viral load can travel up to 8 m during expiratory events,[3] substantially exceeding the present social distancing limits. Furthermore, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been shown to retain infectivity in aerosol form for a minimum of three hours past expiration from an infected person,[5] making it possible for the pathogens to be transported over extended distances due to ambient flows in indoor

environments.[6,11,17–20] The critical importance of safety considerations at indoor workplaces has been recently highlighted by the analysis of various COVID-19 superspreader events,[13] the vast majority of which took place indoors. This underscores the importance of understanding the spread and accumulation of human-borne aerosols in indoor environments through the lens of social distancing, mask usage, occupancy, exposure duration limits, and ventilation.

Another contentious issue brought to the forefront of scientific debates by the COVID-19 pandemic is the efficacy of face masks.[7,8] Although some clinical evidence of respirator mask efficiency existed prior to the COVID-19 pandemic,[21] there is mounting evidence that continuous usage of appropriate face masks can reduce the rate of virus transmission;[7,8] however, the efficacy of different mask types for both the reduction of viral emissions and prevention of individual inhalation of pathogens requires further quantitative analysis.[1,2] This is of particular importance for indoor settings, where PPE can significantly affect the accumulation of the pathogens and their transmission through filtration and reduction/redirection of momentum during expiratory events.

Recent observational studies and meta-analyses of mask effectiveness have estimated that mask usage reduces the risk of respiratory virus spread by 70% to 80%.[22] Efficacy of home-made masks at preventing spread of influenza showed that surgical masks are three times more effective at blocking micro-organism transmission than home-made masks[23–25] although none of these studies include randomized control trials.[26] There is, however, evidence that communities in which masks were in widespread use exhibited significantly reduced community spread.[24,25]

The higher risk of infectious disease transmission in indoor environments, particularly with poor ventilation, has been recognized in the scientific community well before the onset of the COVID-19 pandemic[27] and prompted a number of studies on transmission and aerosol transport indoors.[28–31] The ongoing COVID-19 pandemic has re-invigorated the research efforts in this area due to the growing association between local outbreaks and various indoor settings. For example, Qian *et al.*[13] reported that all except one of the 318 analyzed COVID-19 outbreaks were associated with indoor spaces. Bhagat *et al.*[32] provided an overview of potential effects of ventilation on the indoor spread of COVID-19, and general guidelines for minimizing airborne transmission are detailed in Morawska *et al.*[11] Mittal, Meneveau, and Wu[33] proposed a framework for estimating the risk of airborne transmission of COVID-19 based on probabilistic factors and highlighted the critical need for reliable quantification of key model parameters for future modeling and validation.

The airborne transmission of pathogens in indoor environment is directly related to the dynamics of virus-laden aerosols.[28] The associated transmission risk models are based on either simplified analytical formulations[34–36] or computational fluid dynamics (CFD) tools.[17,33,37] The former typically employ a well-mixed room assumption, where pathogen carrying aerosols are assumed to be instantaneously and uniformly distributed in a given room, such as in the classical Wells–Riley equation.[34] Such simplified modeling has also been employed for COVID-19 risk assessment.[36,38] On the other hand, at the expense of notably higher computational costs and model complexity, CFD-based modeling can provide added insight into spatial evolution of aerosols produced by various expiratory events in realistic indoor environments. Along these lines, a number of studies have modeled airborne spread of COVID-19;[17,39] however, all models rely on quantitative results from experimental studies for an array of input parameters, such as the initial number and size distribution of aerosol particles and initial velocities and duration of expiratory events. Further, the use of PPE, including face masks, needs to be incorporated into computational models, which either significantly complicates the modeling[40] or requires experimental data.[33] Thus, there is a need to incorporate the progress made in a number of recent qualitative and quantitative studies focused on PPE performance into larger-scale investigations focused on aerosol dispersion in indoor environments. This will provide a more comprehensive outlook on workplace health and safety, where the use of PPE is not only often mandated by local legislature, but also can help mitigate the limitation of available ventilation options.

The present study is aimed at bridging the gap between studies focused on face mask efficacy assessment and indoor dispersion of aerosols by experimentally evaluating the aerosol accumulation in a controlled indoor environment, with various types of face masks and ventilation settings considered. Typical nasal breathing is modeled in the present work using a high-fidelity physical model. While this type of expiration is known to produce the lowest aerosol counts per event, this type of breathing is the most common type of expiration and thus accounts for the majority of aerosol production during continuous occupancy at work and public places.[41] A combination of flow visualization, velocity and concentration measurements, and modeling is used to provide a quantitative outlook on the effect of different face masks on aerosol build-up over extended time periods in a generic indoor setting. The result provides critical estimates of apparent filtration efficiency essential for producing adaptive health and safety guidelines for workplaces during pandemic and epidemic events as well as for the development of advanced modeling tools.

II. METHODOLOGY

Experiments were conducted in the Fluid Mechanics Research Laboratory at the University of Waterloo. An overview of the setup is provided in Fig. 1(a). All tests were performed in a $7.8 \times 5.7 \times 2.7$ m room with an air volume of approximately 120 m^3 that was vacated except for the test model and essential equipment. To study the dispersion of exhaled aerosols in an unventilated space, the room was sealed from all surroundings, which included shutting off the ventilation system and sealing all air passageways through the room envelope.

The test model was a Prestan adult CPR manikin (model PP-AM-100-DS), placed upright in a seated position on a chair in the center of the room [Figs. 1(a) and 2(a)]. Breathing with aerosol-laden exhalation was provided by a custom breathing apparatus, the details of which are provided in Fig. 1(b). The positive and negative air pressure cycle was provided by a mechanical ventilator (developed and donated to the project by Crystal Fountains, Inc.), which operated through the repeated compression and decompression of an adult size med-rescuer bag-valve-mask (BVM) (1500 mL bag volume) by a pneumatic piston. Physiological parameters representative of typical adult nasal breathing[42] were set in terms of respiratory period/rate, exhalation time, and breath volume through adjustment of the piston plunging depth, forward and backward stroke speeds, and contact time with the BVM, resulting in the breathing parameters reported in Table I. These parameters were monitored and logged during operation of the ventilator via forward and backward stroke limit switches

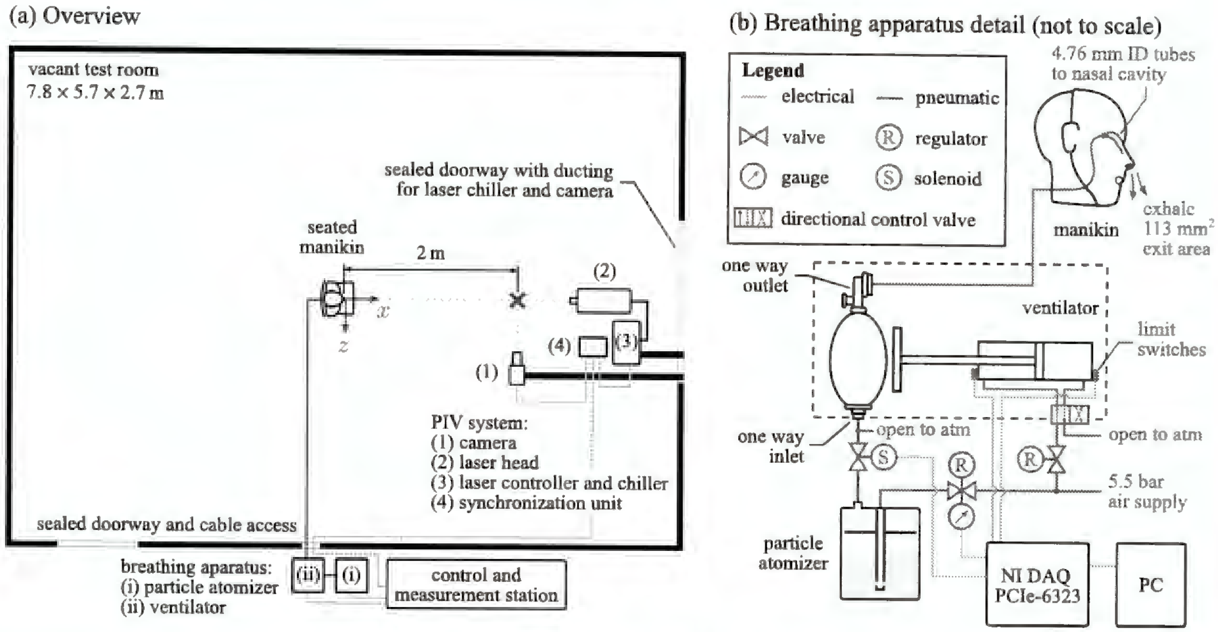

FIG. 1. (a) Overview of the experimental setup and (b) details of the breathing apparatus.

on the piston, with signal sampling performed using National Instruments' LabVIEW software and a PCIe-6323 DAQ.

Aerosols were produced by atomizing olive oil into particles with a mean diameter of about 1 μm (volume-weighted) using a Laskin nozzle style atomizer based on the designs of Kahler, Sammler, and Kompenhans.[43] Controlled injection of particles into the breathing stream was achieved using a normally closed solenoid valve located downstream of the atomizer, the opening of which was synchronized with the breathing cycle through LabVIEW. The solenoid was opened at the start of inhalation (i.e., at the forward stroke limit) and was held open for 2.0 s as this matched the re-inflation time of the BVM without particle injection. The particle production rate was controlled by a pressure regulating valve upstream of the atomizer, the pressure of which was logged in LabVIEW and remained within 0.172 bar ± 0.5 % throughout operation. This pressure level was verified to be below the minimum pressure needed to open the BVM outlet valve, therefore ensuring exhaust from the BVM during the exhalation (compression) portion of the cycle only. Olive oil was selected for the aerosol liquid

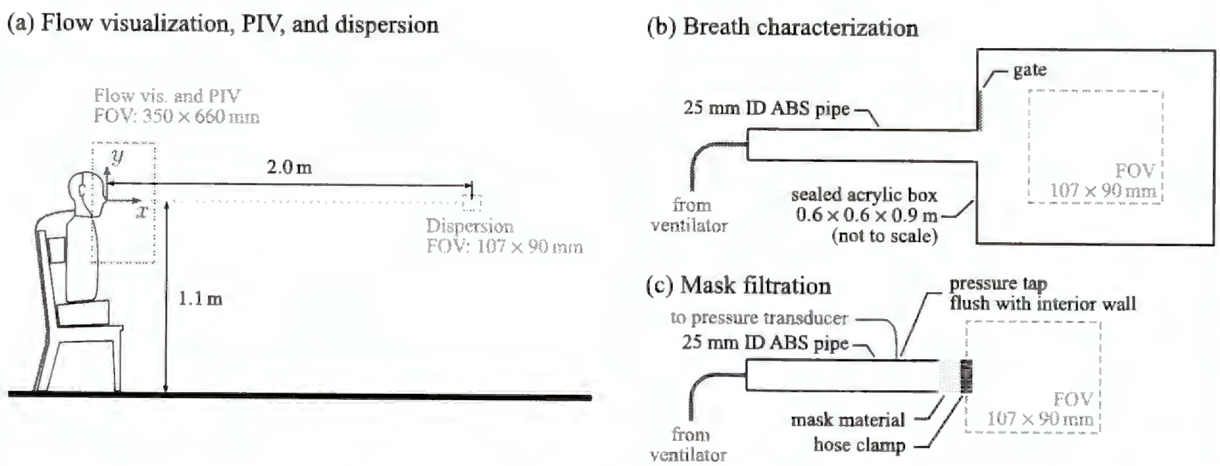

FIG. 2. Profile view of experimental setups for (a) flow visualization, PIV, and dispersion tests, (b) breath characterization, and (c) mask filtration tests.

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TABLE I. Breathing and aerosol production parameters (95% confidence).

Parameter	Value	Unit
Exhalation time	1.75±2%	s
Respiratory period	4.32±2%	s
Respiratory rate	13.9±2%	breath/min
Breath volume	690±3.5%	mL
Avg. exhalation flow rate[a]	0.40±4%	$L\,s^{-1}$
Particles injected	2.75×10^8±7.5%	particles/breath
Breath particle concentration	3.98×10^8±8%	particles/l

[a]Flow rate computed over exhalation time.

component as its use in an atomizer of this design is known to give a polydisperse distribution of particle sizes with a mean diameter of approximately 1 μm,[43] matching the smaller scale of aerosols expelled during typical human respiration,[41,44,45] and the nuclei formed after larger droplets evaporate.[46] Furthermore, oil-based aerosols offer good light scattering properties for optical detection, are charge-neutral,[47] and have a residence time on the order of several hours, in comparison to several minutes for water-based alternatives, which is critical given the approximate one hour viability half-life of the SARS-CoV-2 virus[5] and that virion containing droplet nuclei may remain suspended in air for hours.[7] It should be noted that higher exhalation aerosol concentrations than those typical for normal breathing[41,48,49] was employed (Table I) to reduce measurement uncertainty in experimental aerosol concentration estimates. For consistent data comparison, all concentration measurements are normalized by the initial breath particle concentration, which was maintained constant throughout the study.

The breathing apparatus and measurement control station were located outside of the test room [Fig. 1(a)], with all connections to the interior passed through a sealed cable access. This allowed for tests to be controlled from outside the room, thereby removing any unintended effects the presence of the breathing apparatus, control and measurement equipment, and/or test operators may have had on the results. The output of the ventilator was connected to the manikin using a 12.7 mm inner diameter flexible tube, which was split into two 4.76 mm inner diameter tubes that exhaust into the manikin's nasal cavity. The total nostril exit area was 113 ms^{-1}, which is within the expected range for male adults.[50] The limitations of this experimental setup are the absence of a thermal plume typically present around a human being[42] and that the inhalation does not occur at the manikin, but rather at the inlet of the BVM [Fig. 1(b)].

Qualitative and quantitative measures of aerosol dispersion from the test model were performed using simultaneous illumination and imaging of particles with a laser and digital camera, respectively [Fig. 1(a)]. The methodology constitutes planar particle image velocimetry (PIV) measurements,[51] with the specific equipment employed including an EverGreen 70 mJ/pulse Nd:YAG laser, PCO sCMOS cameras (5.5 MP, 6.5 μm pixel pitch) fitted with 105 mm focal length macro lenses, and a LaVision PTUx timing unit. This equipment was located in the test room, with the air needed for camera and laser cooling supplied through dedicated ventilation ducting connected to a nearby sealed doorway, ensuring no air exchange with the test environment. Control and data acquisition were performed from the exterior measurement station using LaVision's DaVis 10.0 software. The ventilator limit switch signals were passed into the PIV timing unit, allowing for measurement synchronization with the breathing cycle.

Measurements involving the manikin were performed in two locations, both depicted in Fig. 2(a), with the measurement planes located at the mid-span of the test model (within the *x*-*y* plane). The first measurement field of view (FOV) measured 350 × 650 mm, covering the area of exhaled breath for both masked and unmasked cases, and was imaged using two cameras, each at a magnification factor of 0.04. Here, flow visualization and PIV images were acquired at 15 Hz, with the latter requiring aerosol seeding of both the breathing stream and ambient environment. Double-frame PIV images were acquired using frame separation times between 15 and 20 ms, resulting in particle displacement below approximately 20 pixel. The particle images were then processed in DaVis 10 using sliding background subtraction and intensity normalization, followed by an iterative, multi-pass cross correlation algorithm with a final window size of 32 × 32 pixel (50% overlap) to determine local flow velocities at a spatial resolution of 2.98 mm.

At the second measurement location, a single camera was used to image a 107 × 90 mm FOV centered at the height of the exhalation point (1.1 m from the floor) but at a 2 m distance [Fig. 2(a)]. Here, single images were acquired at a rate of 0.25 Hz for up to 10 h in order to track the dispersion of exhaled aerosols from the test subject. In order to minimize the gradients of light intensity within the image, the laser sheet was expanded substantially larger than the dimensions of the field of view (approximately 200% more), such that the core region of the laser beam covered the entire field of view. The directivity of dispersion was investigated by rotating the manikin about the *y*-axis while keeping the measurement location fixed, with orientation angles of 0°, 90°, and 180° considered. For each case, imaged particles (2–3 pixel in the imaging plane) were detected and counted using a particle detection algorithm in DaVis 10.1 software, providing the measure of local particle concentration based on the average over the local measurement volume. The particle detection algorithm measures particle counts by scanning the image for peaks in local intensities after the image is pre-processed using a sliding minimum subtraction and low-pass Gaussian filter to enhance the individual intensity peaks. A threshold for the background noise is employed and kept constant between all the cases for consistency.

A total of seven PPE configurations were considered, with the manikin fitted with (i) no mask, (ii) an unvalved KN95 mask, (iii) a typical three-ply blue pseudo-surgical mask, (iv) a three-ply cotton cloth non-medical mask, (v) a 3M R95 particulate respirator (equivalent to N95 for human borne aerosols), (vi) an unvalved KN95 mask with 3 mm gaps around cheeks and nose, and (vii) a KN95 mask with a single one-way valve on the left side. The parameters presented in Table I were kept constant across all cases. To adjust for a higher average rigidity of the manikin face and have repeatable mask fits, straps typically worn around the ears were tightened by anchoring them to a single peg located inline with the top of the ears and at the center of the back of the head. Note that this was not the case for the R95 respirator, which has straps that circumnavigate the head and neck. Tests with the KN95 mask with artificial gaps [case (vi)] were performed by first ensuring the same baseline fit as that of the unvalved KN95 mask [case (ii)], with the gaps created by 3 mm thick pieces of vinyl foam placed on the cheeks and cheekbones of the manikin, which produced consistent leakage sites similar to the approach employed by Weber

et al.[52] The length of the foam pieces was minimized to reduce blockage while ensuring consistent gap dimensions between multiple runs.

Tests characterizing breath particle concentration, breath volume, and ideal mask filtration efficiency were also performed, with the setups used presented in Figs. 2(b) and 2(c). These tests utilized the same breathing apparatus, breathing parameters, and imaging setup as the dispersion tests, with the outlet of the ventilator fed to a 25 mm inner diameter rigid pipe. For characterization of the breath particle concentration, the outlet of the pipe was fed into an acrylic box (dimensions $0.6 \times 0.6 \times 0.9$ m) which was sealed off after a single breath and images were acquired at 1 Hz for 0.5 h. A uniform particle distribution was reached after approximately 15 min, after which the number of particles was measured. From this, and the FOV area and laser sheet thickness (2.0 mm), the total number of particles contained in the volume and therefore injected by the breath was estimated, resulting in the value reported in Table I. The provided uncertainty range is based on the variance found across ten runs of repeatability.

For breath volume, ideal mask filtration efficiency, and mask pressure drop characterizations, the outlet of the pipe was exhausted to open air and the measurement field of view was moved to the exit of the pipe, as shown in Fig. 2(c). Mask material was sealed around the pipe outlet using a 3 mm thick o-ring and hose clamp. PIV double-frame measurements with a frame separation times of 666 μs were acquired at 15 Hz for the duration of the exhalation over 50 cycles. Image processing was performed in DaVis 10 using sliding background subtraction and intensity normalization, followed by vector calculation using iterative, multi-pass cross correlation with a final window size of 24×24 pixel (75% overlap), yielding a spatial resolution of 0.25 mm. The resulting velocity field data were integrated to give phase average volumetric flow rate, yielding the total breath volume reported in Table I. A pressure tap flush with the interior of the pipe wall was installed two diameters upstream of the pipe exit and was connected to a Setra pressure transducer (Model 264), providing static pressure measurements relative to the local atmospheric pressure. For ideal mask filtration efficiency, the total number of particles exhausted over an exhalation cycle was counted. The result was then compared to the case with no mask, with 50 breath cycles used to establish a confidence interval.

III. RESULTS AND DISCUSSION

This section first discusses the ideal filtration characteristics of various masks used in the present study. Thereafter, the near-field flow visualization and velocity measurements around the face of the test subject are discussed. Finally, the results corresponding to particle dispersion in the test room are presented along with the supporting model results.

A. Baseline mask characteristics

Significant variability in essential mask characteristics has been reported in previous studies, which tends to be more significant for non-certified mask types. Thus, baseline parameters for each mask type considered in the present study have been established experimentally and ensured to be consistent for the same mask types tested here. The baseline ideal filtration characteristics of the studied masks are established for the breathing parameters (Table I) and aerosol employed in the study. An estimate of ideal filtration efficiency, and the associated pressure drop across the mask, is established through tests where the mask is sealed at the point of exhaust [Fig. 2(c), as described in Sec. II], thereby removing the dependency on mask fit to the test model. The results are presented in Fig. 3(a), showing the particle concentration during exhalation, with results averaged over 50 cycles and normalized by the peak concentrations reached in the unfiltered case (no mask).

In Fig. 3(a), for the no-mask case, exhalation begins at approximately 0.5 s, with particle counts downstream of the outlet increasing rapidly after the initiation of the exhalation, followed by an extended period of stabilization at the peak value, and a subsequent decrease in the particle concentration toward the end of the exhalation cycle. A

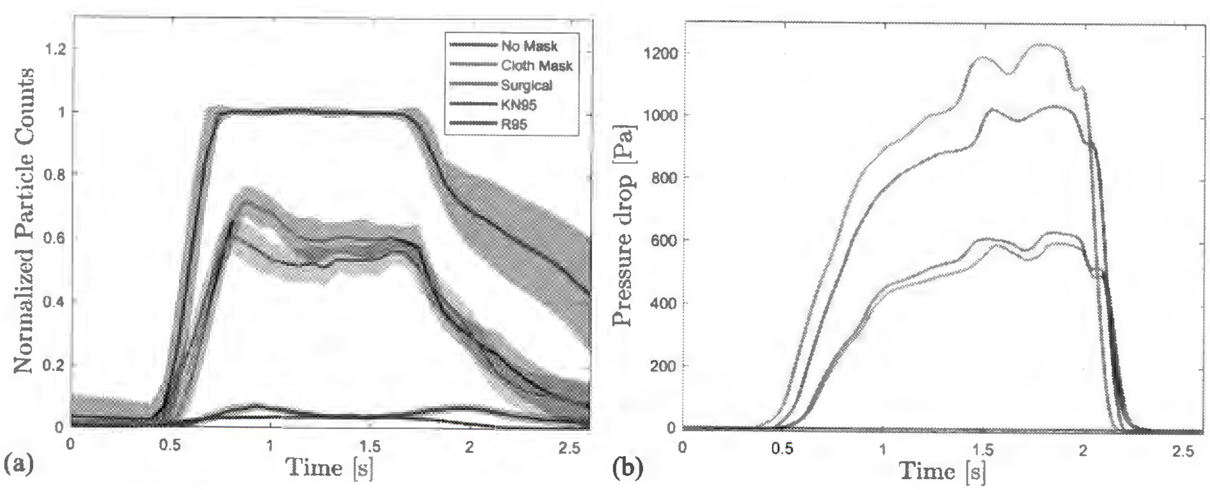

FIG. 3. (a) Particle counts after aerosol particles are passed through various masks and normalized by the particle counts at the plateau in the no-mask case, and (b) associated pressure drop across the mask at a flow rate of 0.4 L s^{-1}. Results are from the setup shown in Fig. 2(c) and are averaged over 50 exhalation cycles. Shaded areas correspond to ± 1 standard deviation. The standard deviations for pressure drop measurements are negligible, and thus, not visible.

similar trend is observed for the tested mask cases, with lower plateau values reached as a result of filtration. The ideal filtration efficiency for a mask is estimated by computing the change in the average particle concentration within the time interval of 1 and 1.5 s, i.e., the plateau value, relative to the no-mask case, with obtained results summarized in Table II. The efficiency of the KN95 and R95 masks is the highest at approximately 95% and 96%, respectively, which agrees well with the rated efficiencies for these masks in the absence of leakage. Such high efficiencies are attributed to the electrostatic filters embedded in these masks, which have been shown to effectively filter both charged and neutrally charged particles.[53,54] Filtration efficiencies for the blue surgical mask and cloth masks are significantly lower at 47% and 40%, respectively, meaning that more than half of the aerosol particles pass through these masks. The present results are in reasonable agreement with Jung *et al.*,[55] who compared filtration efficiencies of a number of medical and non-medical masks. Note that a relatively wide variation of filtration efficiencies has been reported for these types of PPE in previous studies,[56–58] largely attributed to the lack of stringent filtration performance standards.

Pressure drop across a mask and the corresponding flow resistance coefficient ($\Delta P/Q$, where Q is the peak flow rate) are important considerations since both provide measures of mask breathability and, consequently, comfort when worn by an individual, with a lower pressure drop and resistance coefficient indicating higher comfort. The results in Fig. 3(b), along with the parameters summarized in Table II, show that the KN95 and cloth masks have the highest pressure drops and resistance coefficients, indicating relatively poor breathability. In comparison, the pressure drop across the R95 mask is approximately 40% lower than that of the KN95 mask, which is significant given a similar level of filtration efficiency. Pressure drop across the surgical mask is comparable to that of the R95, indicating a similar level of breathability and comfort; however, this comes at the cost of significantly reduced filtration efficiency. It should be noted that substantial variability in measured pressure drop can occur even for the same mask types from different manufacturers;[26,56,57,59,60] however, the trends observed in the present measurements fall within the range of values reported previously. Therefore, these results can serve as a qualitative guide toward the balance between ideal filtration performance and breathability for common face masks.

B. Exhalation flow characterization

With baseline filtration characteristics of the masks established, their effect on the evolution of exhaled breath through the nose of the test model is now considered in the vicinity of the face using particle flow visualization and velocimetry techniques. Results for the KN95 and surgical mask are seen to qualitatively represent a high-efficiency mask and common cloth/non-medical masks, respectively. Thus, these two configurations are used here as representative face mask groups, and the results are contrasted with the no-mask case. Figure 4 illustrates nasal exhalation through an instantaneous flow visualization image at the vertical mid-plane of the face and at a phase angle of 180° within the breathing cycle (exhalation begins at 0°). Multimedia views included for each case depict the flow development over a few breathing cycles. The exhaled flow in the case of no mask [Fig. 4(a) (Multimedia view)] is typical of a transient turbulent jet, with the expelled aerosols directed downwards and the jet front reaching a distance from the nose of approximately 300 mm within approximately 1 s. The turbulent nature of the jet is apparent, with small scale eddies, visualized by particle clouds, present throughout the jet core, with the darker patches around the jet perimeter showing fluid entrained into the jet by turbulent mixing. In fitting the manikin with a mask, both the KN95 and surgical masks [Figs. 4(b) (Multimedia view) and 4(c) (Multimedia view), respectively] are successful in arresting nearly all forward momentum of the exhaled jet. As noted across the literature,[61–63] this is the primary protective mechanism of a mask for direct exposure to aerosols as it serves to reduce and redirect the forward momentum of the exhaled breath, which, as will be shown in Sec. III C, has a significant effect on the dispersion of exhaled aerosols away from the subject over time.

It is important to note that, while masks [Figs. 4(b) (Multimedia view) and 4(c) (Multimedia view)] decrease the forward momentum of the respiratory jet, a significant fraction of aerosol escapes the masks, particularly at the bridge of the nose. Further, aerosols can also be seen in front of the surgical mask due to the lower material filtration efficiency (Table II). These leakages are more readily apparent in the multimedia views. Recent studies employing similar visualization techniques for other types of expiratory events, such as sneezing, coughing, laughing, and speaking,[32,61,64] show similar leakage through surgical and common cloth masks. In those studies, higher pressure differences were imposed and therefore particles passing through the mask may have been expected, while the present results highlight that the pressure difference created by normal breathing is sufficient to cause aerosols to pass through the fabric of a surgical mask. In contrast, such leakage is negligible in the KN95 case [Fig. 4(b) (Multimedia view)], which is representative of high quality, certified masks.

As previously noted, a significant quantity of aerosol escapes at the bridge of the nose in Figs. 4(b) (Multimedia view) and 4(c) (Multimedia view), which highlights the importance of the fit of the mask to the face. Here, the fit of each mask is typical of appropriate usage, with the straps tightened (as outlined in Sec. II) and the built-in wire shaped to the bridge of nose. Nonetheless, aerosols escape at the perimeter of the mask due to inevitable imperfections in the mask fit, with the most significant quantity of particles escaping at the bridge of the nose. Other leakage sites include the interface of the mask edges with the cheeks and lower jaw [not captured in Figs. 4(b) (Multimedia view) and 4(c) (Multimedia view) due to laser sheet positioning]; however, these results and other supplementary measurements (not shown for brevity) confirm that leakage at the bridge of the nose far exceeds all other leakage points. At the bridge of the nose, the particle clouds that escape the masks are relatively dense in comparison to the exhaled

TABLE II. Filtration characteristics of various masks at an integrated flow rate of 0.4 L s^{-1}. ΔP and P_{dyn} indicate the peak pressure drop and the peak dynamic pressure, respectively, obtained at the peak flow rate ($Q = 0.61$ L s^{-1}). The 95% confidence intervals on the mean filtration efficiencies and peak pressure drop are within ±1.5% and ±0.25%, respectively, for all the cases.

Mask material	Filtration efficiency (%)	ΔP (Pa)	$\Delta P/P_{dyn}$	$\Delta P/Q$ (Pa s/m^3 × 10^{-5})
Cloth	40	1196	1356	19.67
Surgical	47	573	650	9.42
KN95	95	1014	1150	16.68
R95	96	606	687	9.97

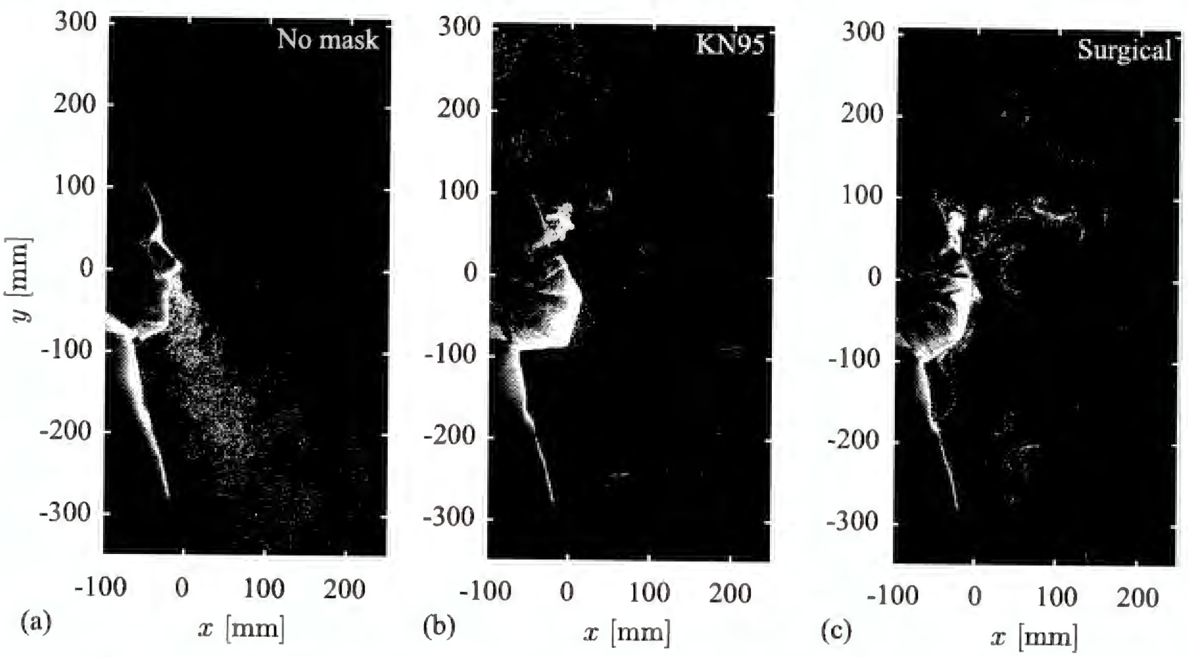

FIG. 4. Instantaneous flow visualizations at 180° within the breathing cycle for the (a) no mask, (b) KN95, and (c) surgical mask cases. Multimedia views: https://doi.org/10.1063/5.0057100.1; https://doi.org/10.1063/5.0057100.2; https://doi.org/10.1063/5.0057100.3

jet in the no-mask case, which is attributed to the significant redirection of momentum needed to force particles out at the top of the mask, resulting in much lower exit velocities and hence reduced turbulent diffusion. The observed particle concentrations just outside the mask qualitatively agree with the results of Sickbert-Bennett *et al.*[55,66] who obtained fitted filtration efficiency (FFE) estimates of more than 95% for inhalation with N95 type masks. However, their FFE estimates are based on the particle concentration entering the mask from the ambient air and are not directly indicative of the mask efficiency when considering the exhalation of aerosols. The results in Fig. 4 illustrate that a notable amount of particles leak out at the perimeter of all masks, which is expected to result in notably lower effective filtration efficiency, compared to ideal filtration efficiency, when exhalation is considered.

Figure 5 presents phase-averaged velocity fields, again at a phase angle of 180° within the breathing cycle, matching Fig. 4. Multimedia views are also provided for each case, showing phase-averaged velocity field development over the full exhalation cycle. Note that these measurements were performed at the mid-plane of the manikin face, not at the center of a given nostril. For the case with no mask [Fig. 5(a) (Multimedia view)], typical turbulent jet characteristics are noted, with jet propagation and spreading rate typical of accelerating jet flows.[67] Within the measurement plane, peak velocities range from 0.10 to 0.12 ms^{-1} in the core of the jet, which is within the range of velocities investigated in previous studies for normal breathing.[53,56,68–71] The results confirm that the forward momentum is decreased dramatically when the subject is fitted with a mask [Figs. 5(b) (Multimedia view) and 5(c) (Multimedia view)], as was seen in the flow visualizations (Fig. 4). For these cases, the expelled flow is directed primarily upward and backward by the mask and remains attached to the forehead due to the Coanda effect, with peak velocities reduced to less than 0.10 ms^{-1}. For the surgical mask, the flow that penetrates through the front of the mask is of relatively low forward momentum and, consequently, much lower penetration depth, as seen in Fig. 4(c) (Multimedia view). Together, the flow visualization and PIV results (Figs. 4 and 5, respectively) highlight important safety aspects when considering aerosols dispersed by an individual's breathing. When not fitted with a mask, exhalation from the nose produces a relatively strong turbulent jet containing well mixed particles that will disperse relatively quickly away from the subject. While in the case of equipping a mask, the jet momentum is significantly reduced and redirected, leading to leakages of aerosols at any point where the mask does not maintain a tight seal to the face. Based on the results obtained here, the leakages are most significant at the bridge of the nose, leading to dense aerosol clouds exiting near and remaining close to the fore and top of the head.

C. Aerosol dispersion in an indoor environment

Noting the significance of both the ideal filtration characteristics (Sec. III A) and fit of a mask (Sec. III B), it is apparent that both effects must be taken into account in order to provide an accurate measure of the effectiveness of a mask in reducing the dispersion of an aerosol exhaled by an individual. This is investigated through the measurement of aerosol dispersion from the test model in a vacant indoor space over a period of 10 h, with the particle concentration measured at a 2 m distance from the subject [Fig. 2(a)], aligned with the widely accepted social distancing recommendations.

In an enclosed space with negligible convective effects, such as the room in which the tests are conducted, the concentration of

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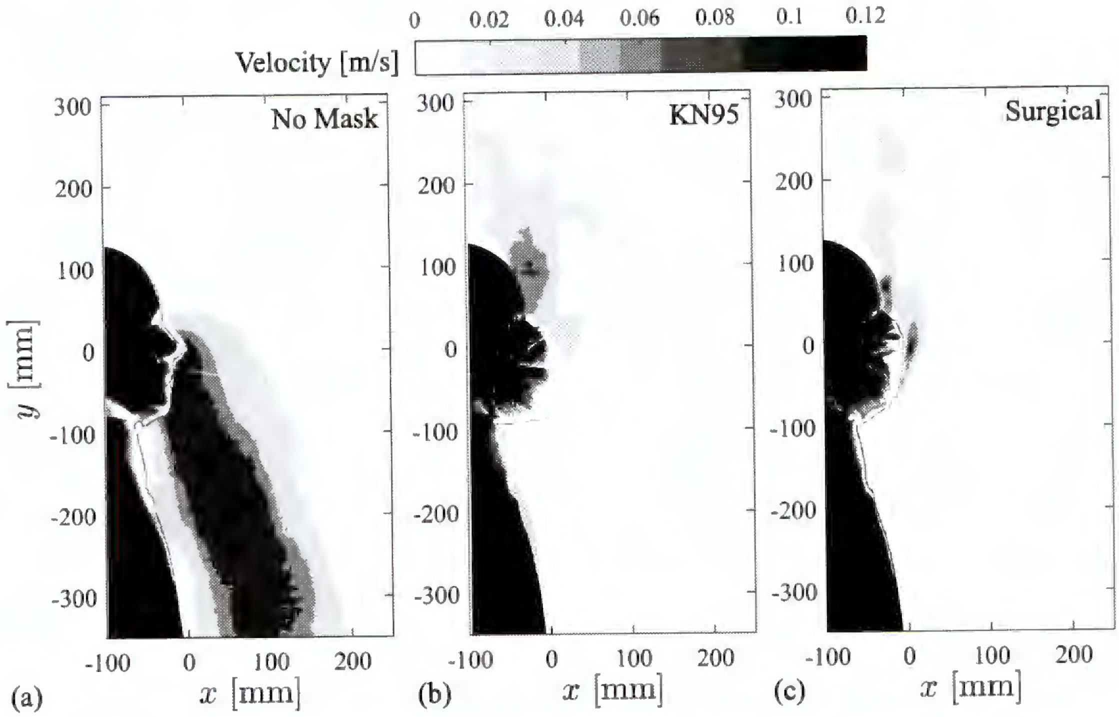

FIG. 5. Phase-averaged velocity fields at 180° within the breathing cycle for the (a) no mask, (b) KN95, and (c) surgical mask cases. Multimedia views: https://doi.org/10.1063/5.0057100.4; https://doi.org/10.1063/5.0057100.5; https://doi.org/10.1063/5.0057100.6

dispersed aerosols away from the source is governed by the unsteady diffusion equation

$$\frac{dc}{dt} = \nabla \cdot (K\nabla c) + R - \lambda c, \tag{1}$$

where c is the concentration of aerosol particles (particles m^{-3}), t is time, K is the diffusion coefficient ($m^2\ s^{-1}$), R is the particle injection rate (particles $m^{-3}\ s^{-1}$), and the sink term containing the decay rate λ (s^{-1}) which takes into account particle decay.[15]

While Eq. (1) has been used for modeling in a number of previous studies,[17,32,35,72] the model outcomes are predicated on appropriate estimation of the injection rate, decay, and diffusion terms, with the commonly employed coarse estimates only providing qualitative understanding of the spatial and temporal evolution of particle concentration for various room and source configurations. In practice, it is extremely challenging to obtain reasonable estimates for these values,[32] while computational results remain extremely sensitive to these parameters.

A significant simplification to Eq. (1) is commonly employed by assuming instantaneous distribution of produced aerosols in the room as in the following equation:

$$\frac{dc}{dt} = R - \lambda c. \tag{2}$$

The solution to Eq. (2), subject to the initial condition $c^*(t = 0) = 0$, is given by

$$c^*(t) = \frac{R^*}{\lambda^*}(1 - e^{-\lambda^* t}). \tag{3}$$

For the purposes of practical data assimilation considered in the present study, the underlying simplification absorbs the effect of diffusion into the sink and source terms. This makes the solution dependent on the spatial location, and the relevant parameters are marked with an asterisk (c^*, R^*, λ^*). Equation (3) models the temporal evolution of concentration in a typical first-order fashion with a saturation concentration of $c^*_{sat} = R^*/\lambda^*$. Although previous studies have noted significant deviations of diffusion-based computational results from the well-mixed model,[72–74] the simplified model will be shown to fit well with the experimental data and thus provides a suitable comparison basis for saturation conditions. The latter allows for relative source strength comparisons between different test cases, which is of particular importance for the evaluation of the apparent mask filtration efficiency.

Experimental results from the aerosol dispersion tests are presented in Fig. 6, with results normalized by the average particle concentration of a single breath (Table I) and smoothed using a 10 min moving average. For clarity, the variability between repeated measurements is illustrated by the shaded regions only in the no-mask and KN95 cases, which are representative of the typical variability observed in all the tested cases. In Fig. 6(b), the results are also plotted on a logarithmic scale and are fitted based on the typical first-order behavior described by Eq. (3). The obtained least squares fit parameters are presented in Table III, with the corresponding confidence intervals determined based on repeated tests.

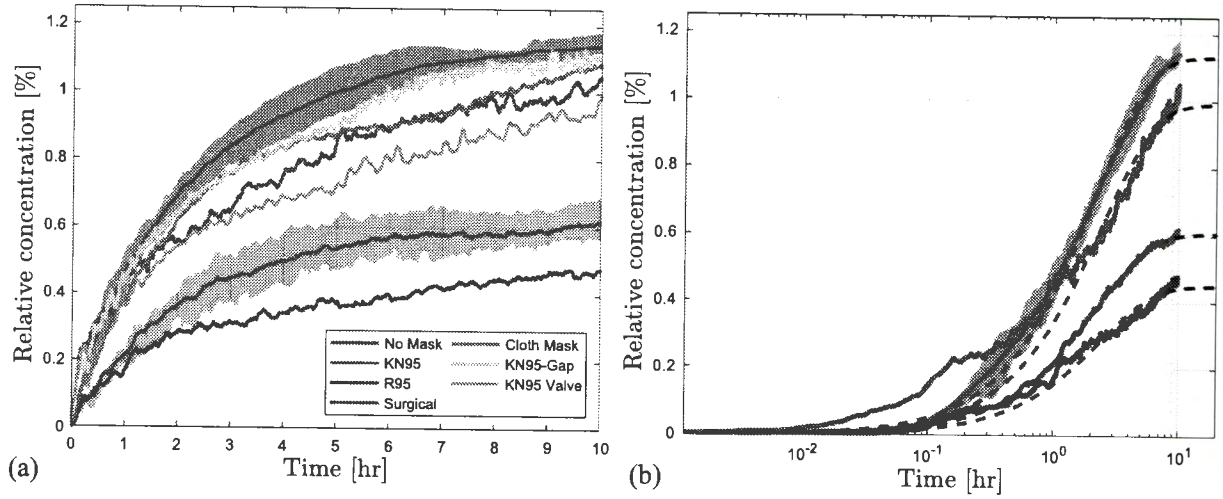

FIG. 6. Effect of various masks on the dispersion of aerosols measured at 2 m in front of the manikin. (a) Results are smoothed using a 10 min moving average. (b) Moving average particle concentration on semi-logarithmic scale for selected cases with a black dashed line showing model fits. Shaded areas show variability within repeated runs.

It can be seen that the simplified model captures the essential concentration trends well. The average relative concentration in the no-mask case is seen to asymptotically tend to the local steady state value of 1.13% of the breath particle concentration after a period of 10 h. Upon fitting various masks to the manikin, the relative concentrations are lowered in comparison to the no-mask case, indicating a reduction in the source strength due to filtration. The same is also captured in the reduction of the relative particle injection rate. However, the relative changes in the injection rate are significantly lower than those expected purely based on the ideal filtration efficiency of the mask material (Table II), which is attributed to the substantial aerosol leakage seen in Fig. 4.

Given close adherence of the experimental data to Eq. (3), the estimated saturated, i.e., steady state, concentration levels can be used to deduce the apparent filtration efficiency of the masks,

$$\eta_{AFE} = 100 \times \left(\frac{c^*_{sat_{NoMask}} - c^*_{sat}}{c^*_{sat_{NoMask}}} \right). \tag{4}$$

TABLE III. Apparent filtration characteristics of various masks based on particle dispersion tests over 10 h. R^* ((%/h) of the breath particle concentration) and λ^* (h^{-1}) are fit parameters estimated using a multi-variable least squares fit of Eq. (3) to the experimental data in Fig. 6. Values for the parameters are shown with a 95% confidence interval based on the t-statistic. Confidence interval on η_{AFE} incorporates the variation in the no-mask case.

Material	R^* (%h)	λ^* (h^{-1})	$c^*_{sat} = R^*/\lambda^*$ (%)	η_{AFE} (%)
No mask	0.53 ± 0.11	0.46 ± 0.11	1.13 ± 0.057	...
Cloth	0.45 ± 0.27	0.44 ± 0.31	1.02 ± 0.11	9.8 ± 9.7
Surgical	0.41 ± 0.36	0.41 ± 0.39	0.99 ± 0.11	12.4 ± 9.7
KN95	0.27 ± 0.10	0.45 ± 0.12	0.61 ± 0.095	46.3 ± 9.4
R95	0.19 ± 0.09	0.42 ± 0.11	0.45 ± 0.09	60.2 ± 9.0
KN95-gap	0.46 ± 0.16	0.42 ± 0.21	1.09 ± 0.09	3.4 ± 8.9
KN95-valve	0.37 ± 0.12	0.41 ± 0.14	0.90 ± 0.09	20.3 ± 8.9

The resulting estimates for the apparent filtration efficiency (η_{AFE}) are reported in Table III, which confirms that η_{AFE} for all the masks is significantly lower than the filtration efficiencies for their respective materials presented in Table II. The R95 mask has the highest η_{AFE} of 60.2%, which is attributed to the tighter fit of the mask obtained by the overhead straps, a relatively stiff fabric, and the built-in soft sealing layer at the nose bridge of the mask. For KN95 mask, the gaps along the cheeks and the nose bridge are found to be comparatively larger, which leads to a lower η_{AFE} despite a similar filtration efficiency of the material. The cloth and surgical masks perform relatively poorly with efficiencies of only 9.8% and 12.4%, respectively, due to both low material filtration efficiency and significantly higher amounts of leakages around the cheeks and bridge of the nose. Further, due to the higher flexibility of the cloth and surgical mask material, they easily deform during exhalation, causing an increase in the size of the preexisting gaps, allowing more aerosols to escape.

In order to further evaluate the effect of leakage through the gaps around the cheeks and the nose, a separate case with the KN95 mask was considered with 3 mm gaps created artificially, as described in Sec. II. The 3 mm gaps are representative of the typical gaps observed for the surgical and cloth masks and provide a "loose-fitting" KN95 case. Results for the KN95-gap case in Fig. 6 and Table III show a significant reduction in the filtration efficiency compared to the baseline KN95 mask, with η_{AFE} decreasing from 46.3% to a paltry 3.4%. This offers a holistic perspective on the implications of loose fitting masks and aerosol build-up, in contrast with the results of Sickbert-Bennet *et al.*[17] whose single-point measurement directly behind the mask shows an efficiency (FFE) of more than 90% with a sub-optimally fit N95 mask. An additional point of comparison is provided in the present study by an appropriately fitted KN95 mask equipped with a one-way valve, which has an apparent efficiency of approximately 20%. This illustrates that controlled discharge through a valve on a high-efficiency mask may lead to a better overall exhale filtration compared to either a lower-grade mask (cloth or surgical) or a loosely fitted high-efficiency mask.

An important aspect of mask usage that is not apparent in Fig. 6 due to temporal smoothing and averaging over repeated runs is illustrated in Fig. 7, which presents raw particle concentrations for a selected subset of test cases. The instantaneous particle concentrations measured within the field of view in Fig. 7(a) show large temporal variations in local concentrations when masks are used, which consistently exceed those seen for the no-mask case. The instantaneous magnitudes of particle concentrations reach up to 1.6% of the single breath concentration in the case of blue surgical mask, roughly 40% above the saturation concentration reached in the no-mask case. These maximum excursions in the cases of the KN95 and R95 masks are lower; however, the instantaneous spikes in concentration surpass the average no-mask concentration in the first hour of the test. These excursions in the local particle concentrations are attributed to the presence of dense particle clouds that frequently pass through the field of view, as illustrated in Fig. 7(b). The figure shows representative concentration maps of the particle clouds in the blue surgical and the KN95 mask cases. Peak concentrations reach up to 3% of the particle breath concentrations in the blue surgical mask case, which are localized within the core regions of the clouds and indicate a much higher threat than that perceived based on the averaged results in Fig. 6. Although these particle clouds were present in every tested case with a mask, their frequency and sizes decreased for masks with better fits and higher apparent filtration efficiencies (η_{AFE}), as illustrated by representative realizations for KN95 and R95 masks in Fig. 7(b). The implication for disease mitigation is a significant temporal variability in the exposure risk associated with masks in an unventilated indoor environment. Recent studies[72,73] have noted similar concentration excursions attributed to the local flows, exceeding the predictions based on the well-mixed and diffusion based models.

It is of practical interest to investigate the directivity of the exhaled particles for social distancing purposes in indoor environments with poor ventilation. Directivity of the particle dispersion at the 2 m distance from the source was investigated in the no-mask and KN95 cases, and the results are presented in Fig. 8. The results for the no-mask case in Fig. 8(a) show that the average concentrations reached at 90° and 180° decrease in comparison to those at 0°, but the effect of the orientation is less than 10%. In the case of KN95 mask [Fig. 8(b)], the particle concentrations at the non-zero orientations are only slightly higher than those at 0°. While the general trend highlighted by these results is in accordance with the expectations based on the flow visualization results (Fig. 4), the differences with orientation are relatively minor which indicates that the anticipated effect of directivity due to advection is primarily confined to the near vicinity of the source. In the absence of ventilation effects, turbulent diffusion appears to largely equalize the concentration along the circumferential direction at and beyond the 2 m radial distance surrounding the source. This is in accordance with the typical deposition mechanisms observed in the case of suspended particles.[75] However, the observed effect may be limited to relatively large room sizes, such as those used in the current experiment, where the advection effects near the source become negligible well inside the boundaries of the room. The current results are in qualitative agreement with the results from diffusion based models[37] in a poor ventilation scenario.

Finally, the effect of room ventilation and/or air cleaning is investigated on the aerosol dispersion 2 m in front of the manikin. Measurements are conducted at three different settings of a mobile air purifier installed in the corner of the room (left top corner in Fig. 1). Due to a high efficiency particle air (HEPA) filtration (>99% efficiency), the unit allows a controlled modeling of ventilation settings, with effective air-change rates (ACH) of 1.7, 2.45, and 3.2 h^{-1} considered in the present investigation. The results presented in Figs. 9(a) and 9(b) show a notable reduction in local concentration in front of the manikin even with relatively low effective air-change rates, as also noted by previous studies[35,73]) The measured concentrations are seen to decrease with increasing ACH, and the steady-state (c^*_{sat}) is achieved

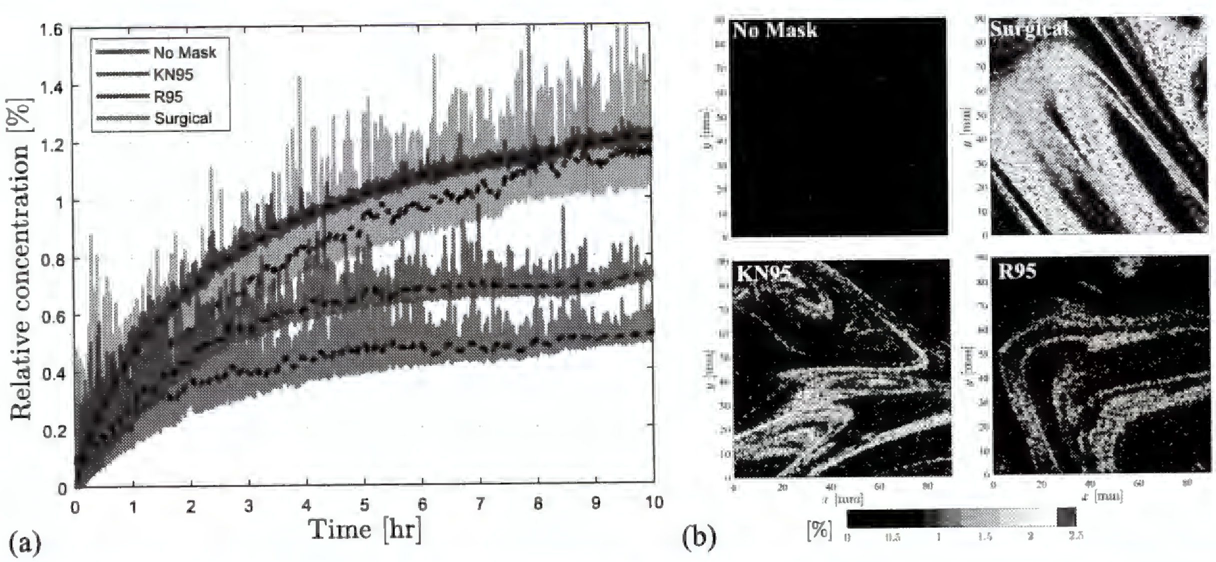

FIG. 7. (a) Raw particle concentration for representative test cases considered in Fig. 6 with moving average shown with black dashed lines. (b) Instantaneous relative particle concentration fields for the selected cases. Relative concentrations are represented as a fraction of the breath particle concentration.

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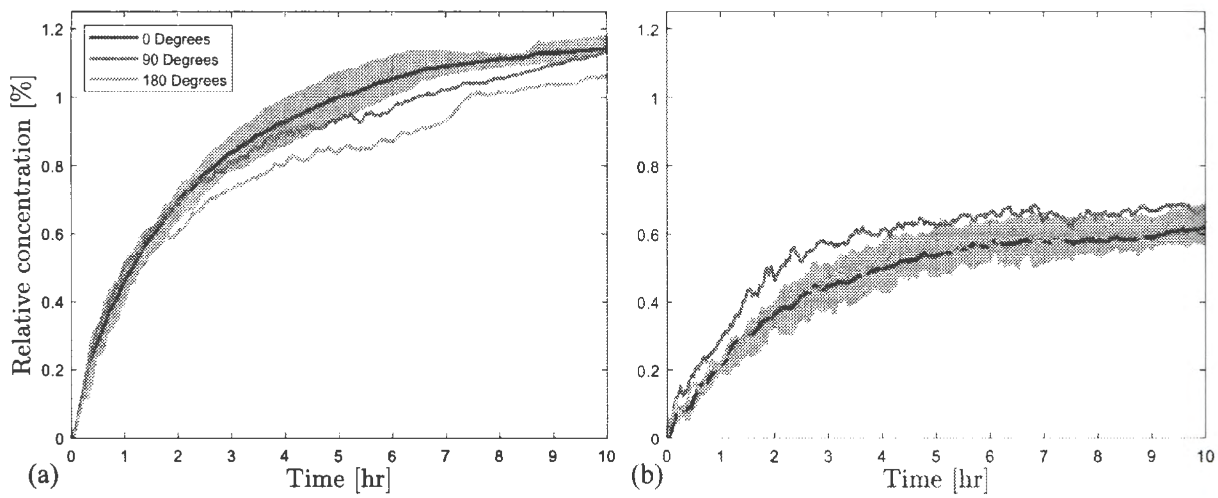

FIG. 8. Dispersion characteristics of the aerosols measured at a radius of 2 m from the manikin for (a) no mask and (b) KN95 mask.

within less than 4 h in all the air-cleaning cases. The results are fitted to the simplified model [Eq. (3)] in Fig. 9(b), and the fits are seen to approximate the data well. The corresponding fit parameters are summarized in Table IV. As expected, the increase in ACH results in a notable increase in the decay rate (λ^*), which is reflected in the earlier saturation of the local concentration. This is also in accordance with the increased diffusion coefficient in mixing ventilation scenarios as shown by Foat *et al.* and Cheng *et al.* at comparable ACH. The steady-state values are used to estimate an apparent filtration efficiency (η_{AFE}) of the system in order to draw meaningful comparisons with the results from the mask cases in an unventilated scenario. In this case, the apparent filtration efficiency (η_{AFE}) is obtained by the relative change in the steady-state concentration (c^*_{sat}) between the ventilated and unventilated cases. The results in Table IV show that the steady-state concentrations are decreased in the range 69%–84% for the considered cases and correspond to a much higher η_{AFE} compared with the best performing mask in an unventilated scenario (Table III). However, this also suggests that relatively low ventilation rates (ACH $< 3.2\,h^{-1}$) may not be sufficient to reduce exposure to within acceptable levels at the typical social distancing guideline of 2 m, which supports the findings from previous studies.

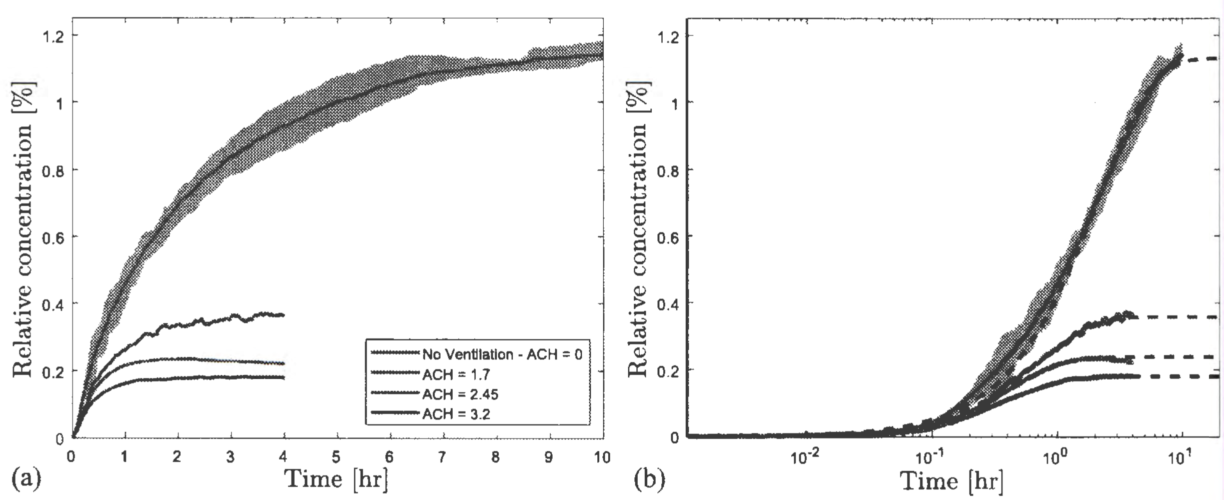

FIG. 9. Effect of ventilation on the dispersion characteristics of the aerosols measured at 2 m in front of the manikin without a mask on a (a) linear, and (b) logarithmic scale in time. Black dashed line indicates model fits to the moving average data.

TABLE IV. Apparent filtration efficiencies for various air-change rates (ACH) based on particle dispersion tests with no-mask. R^* ((%/h) of the breath particle concentration) and λ^* (h^{-1}) are fit parameters estimated using a multi-variable least squares fit of Eq. (3) to the experimental data in Fig. 9.

ACH	R^* (%/h)	λ^* (h^{-1})	$c^*_{sat} = R^*/\lambda^*$ (%)	η_{AFE} (%)
0	0.53	0.46	1.13	...
1.7	0.48	1.36	0.35	69
2.45	0.52	2.19	0.24	79
3.2	0.41	2.27	0.18	84

IV. CONCLUSIONS

The present study experimentally investigates the dispersion and accumulation of aerosol particles in indoor environments in the context of the guidelines proposed by national health agencies to control the transmission of COVID-19. Experiments were conducted in a controlled laboratory environment with a test manikin in a seated position mimicking relaxed exhalation through the nose, typical of an average adult. The manikin was equipped with five different commercially available masks that have seen widespread use throughout the course of the COVID-19 pandemic. Both near-field flow visualizations and far-field particle concentration measurements allow for a holistic investigation of the effect of masks and ventilation in the test room, and provide a quantitative measure relative to aerosol concentrations and mask efficiencies of interest for transmission risk assessment, model development, and implementation of adaptive health and safety practices at workplace. The results highlight that (i) considerable relative aerosol concentration levels can be reached at a 2 m distance from the subject in an unventilated space, and even when the subject is equipped with a mask, the relative concentrations are notably higher than those expected based on the ideal/rated efficiency of the masks; (ii) fit of the mask to the face, in terms of limiting leakage around the mask perimeter, is critical for limiting aerosol dispersion in an unventilated space, especially for high efficiency masks (e.g., N95/KN95); and (iii) increased ventilation/air-cleaning capacity significantly reduces the transmission risk in an indoor environment, surpassing the apparent mask filtration efficacy even at relatively low air-change rates (~2 room volumes per hour).

The baseline filtration characteristics for the various masks tested in this study indicate that more than 50% of aerosols (polydisperse, 1 μm mean diameter) can pass through the material of commercially available cloth and surgical masks in ideal conditions (zero leakage due to fit), whereas ideal filtration efficiency is 95% (or higher) in the case of KN95 and R95 masks. Flow visualizations and velocity measurements in the near-field (immediate vicinity of the face) indicate that none of the tested masks is performing at their ideal filtration efficiencies due to leakages through gaps in the fit of the mask. This occurs around the cheeks, below the jaw, and at the bridge of the nose, with the latter being the most significant for all masks. Aerosols are seen to escape through these leakage sites in the form of concentrated particle clouds that do not mix quickly with the ambient air on account of relatively low flow velocities and hence low levels of turbulent mixing. The degree of leakage varies between masks, with high-efficiency masks, such as the KN95, performing better. Factors affecting leakage at the mask perimeter include mask geometry, strap style and elasticity, and whether or not the mask is equipped with a deformable nose piece that can be tightly shaped to the nose. Furthermore, although the present study does not characterize the effectiveness of masks during inhalation, the aforementioned loss of filtration efficiency due to perimeter leakage is also expected to be present during inhalation, although it is to a lesser extent due to the improved sealing effect produced by the negative pressure difference relation to the ambient.

The near-field velocity measurements indicate that the forward momentum of breath exhaled through the nose is reduced significantly and redirected when the subject is equipped with a mask. Furthermore, this attenuation of the forward momentum increases with the filtration efficiency of the mask material when a proper fit is ensured. Thus, the present results endorse the use of high-efficiency, unvalved masks with a proper fit when the recommended social distancing guidelines cannot be maintained between individuals.

Measurements of aerosol concentration at a 2 m distance from the subject show a characteristic increase in average particle concentration with time in the absence of ventilation, following the first order response based on the well-mixed room model. Across all cases, relative particle concentrations saturate at elevated levels, indicating accumulation of aerosol particles within the room. When the subject is not fitted with a mask, the saturation concentration is the highest among all the cases tested. A decrease in saturation concentration is seen for all mask types; however, the effective filtration is notably lower than the ideal filtration efficiency of the material due to leakages in accordance with a mask's ability to decrease the number of particles released into the room per breath. Thus, the apparent filtration efficiency of a mask (η_{AFE}) is estimated based on the relative difference in saturation concentration at the measurement location between cases with and without a mask. This metric provides a more representative measure of mask efficiency and is of particular interest for future modeling studies and continuous occupancy risk assessment.

The results show that a standard surgical and three-ply cloth masks, which see current widespread use, filter at apparent efficiencies of only 12.4% and 9.8%, respectively. Apparent efficiencies of 46.3% and 60.2% are found for KN95 and R95 masks, respectively, which are still notably lower than the verified 95% rated ideal efficiencies. Furthermore, the efficiencies of a loose-fitting KN95 and a KN95 mask equipped with a one-way valve were evaluated, showing that a one-way valve reduces the mask's apparent efficiency by more than half (down to 20.3%), while a loose-fitting KN95 provides a negligible apparent filtration efficiency (3.4%). The present results provide an important practical contrast to many other previous experimental and numerical investigations, which do not consider the effect of mask fit when locally evaluating mask efficiency or incorporating mask usage in a numerical model. Nevertheless, if worn correctly, high-efficiency masks still offer significantly improved filtration efficiencies (apparent and ideal) over the more commonly used surgical and cloth masks, and hence are the recommended choice in mitigating the transmission risks of COVID-19.

The directivity of aerosol dispersion was assessed through concentration measurements at a 2 m distance and at locations in front of (0°), to the side of (90°), and behind (180°) the subject with a surgical and KN95 masks. For all the cases, the effect of orientation was less than about 10% of the local particle concentration and indicated a relatively minor directivity effect at a distance of 2 m. It is conjectured

based on the flow measurements in the vicinity of the manikin face that significant directivity effects are confined to the relatively close proximity of the host.

The effect of ventilation/air-cleaning was consider using a HEPA air purifier at the recommended pre-pandemic air-change rates ($\mathrm{ACH} = 1.7$–$3.2\,\mathrm{h}^{-1}$). The results show that ventilation air-exchange or purification is effective in decreasing both the final saturation concentration and the time required to reach the saturation state. Based on the apparent filtration efficiency, tests performed with no mask at an air-change rate of $1.7\,\mathrm{h}^{-1}$ (and higher) outperform cases with high-efficiency masks (KN95 and R95) and no room ventilation. However, at these low ventilation rates, a notable particle concentration is still present at a 2 m distance, which is indicative of higher ventilation rates needed to ensure negligible aerosol build-up over prolonged occupancy.

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DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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EXHIBIT v

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Review

Is a Mask That Covers the Mouth and Nose Free from Undesirable Side Effects in Everyday Use and Free of Potential Hazards?

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Abstract: Many countries introduced the requirement to wear masks in public spaces for containing SARS-CoV-2 making it commonplace in 2020. Up until now, there has been no comprehensive investigation as to the adverse health effects masks can cause. The aim was to find, test, evaluate and compile scientifically proven related side effects of wearing masks. For a quantitative evaluation, 44 mostly experimental studies were referenced, and for a substantive evaluation, 65 publications were found. The literature revealed relevant adverse effects of masks in numerous disciplines. In this paper, we refer to the psychological and physical deterioration as well as multiple symptoms described because of their consistent, recurrent and uniform presentation from different disciplines as a Mask-Induced Exhaustion Syndrome (MIES). We objectified evaluation evidenced changes in respiratory physiology of mask wearers with significant correlation of O_2 drop and fatigue ($p < 0.05$), a clustered co-occurrence of respiratory impairment and O_2 drop (67%), N95 mask and CO_2 rise (82%), N95 mask and O_2 drop (72%), N95 mask and headache (60%), respiratory impairment and temperature rise (88%), but also temperature rise and moisture (100%) under the masks. Extended mask-wearing by the general population could lead to relevant effects and consequences in many medical fields.

Keywords: personal protective equipment; masks; N95 face mask; surgical mask; risk; adverse effects; long-term adverse effects; contraindications; health risk assessment; hypercapnia; hypoxia; headache; dyspnea; physical exertion; MIES syndrome

1. Introduction

At the beginning of the spread of the novel pathogen SARS-CoV-2, it was necessary to make far-reaching decisions even without available explicit scientific data. The initial assumption was that the pandemic emergency measures were set in place to reduce the acute threat of the public health system effectively and swiftly.

In April 2020, the World Health Organization (WHO) recommended the use of masks only for symptomatic, ill individuals and health care workers and did not recommend its widespread use.

In June 2020, they changed this recommendation to endorse the general use of masks in, e.g., crowded places [1,2]. In a meta-analysis study commissioned by the WHO (evidence level Ia), no clear, scientifically graspable benefit of moderate or strong evidence was derived from wearing masks [3].

While maintaining a distance of at least one meter showed moderate evidence with regard to the spreading of SARS-CoV-2, only weak evidence at best could be found for masks alone in everyday use (non-medical setting) [3]. Another meta-analysis conducted in the same year confirmed the weak scientific evidence for masks [4].

Accordingly, the WHO did not recommend general or uncritical use of masks for the general population and expanded its risk and hazard list within just two months. While the April 2020 guideline highlighted the dangers of self-contamination, possible breathing difficulties and false sense of security, the June 2020 guideline found additional potential adverse effects such as headache, development of facial skin lesions, irritant dermatitis, acne or increased risk of contamination in public spaces due to improper mask disposal [1,2].

However, under pressure from increasing absolute numbers of positive SARS-CoV-2 tests, many prescribers further extended mask-wearing according to certain times and situations, always justified by the desire to limit the spread of the virus [5]. The media, numerous institutions and most of the population supported this approach.

Among the medical profession and scientists, the users and observers of medical devices, there have been simultaneous calls for a more nuanced approach [6–8]. While there has been a controversial scientific discussion worldwide about the benefits and risks of masks in public spaces, they became the new social appearance in everyday life in many countries at the same time.

Although there seems to be a consensus among the decision makers who have introduced mandatory masks that medical exemptions are warranted, it is ultimately the responsibility of individual clinicians to weigh up when to recommend exemption from mandatory masks. Physicians are in a conflict of interest concerning this matter. On the one hand, doctors have a leading role in supporting the authorities in the fight against a pandemic. On the other hand, doctors must, in accordance with the medical ethos, protect the interests, welfare and rights of their patient's third parties with the necessary care and in accordance with the recognized state of medical knowledge [9–11].

A careful risk–benefit analysis is becoming increasingly relevant for patients and their practitioners regarding the potential long-term effects of masks. The lack of knowledge of legal legitimacy on the one hand and of the medical scientific facts on the other is a reason for uncertainty among clinically active colleagues.

The aim of this paper is to provide a first, rapid, scientific presentation of the risks of general mandatory mask use by focusing on the possible adverse medical effects of masks, especially in certain diagnostic, patient and user groups.

2. Materials and Methods

The objective was to search for documented adverse effects and risks of different types of mouth–nose-covering masks. Of interest here were, on the one hand, readymade and self-manufactured fabric masks, including so-called community masks and, on the other hand medical, surgical and N95 masks (FFP2 masks).

Our approach of limiting the focus to negative effects seems surprising at first glance. However, such an approach helps toprovide us with more information. This methodology is in line with the strategy of Villalonga-Olives and Kawachi, who also conducted a review exclusively on the negative effects [12].

For an analysis of the literature, we defined the risk of mouth–nose protection as the description of symptoms or the negative effects of masks. Reviews and expert presentations from which no measurable values could be extracted, but which clearly present the research situation and describe negative effects, also fulfill this criterion.

Additionally, we defined the quantifiable, negative effect of masks as the presentation of a measured, statistically significant change in a physiological parameter in a pathological direction ($p < 0.05$), a statistically significant detection of symptoms ($p < 0.05$) or the occurrence of symptoms in at least 50% of those examined in a sample ($n \geq 50\%$).

Up to and including 31 October 2020, we conducted a database search in PubMed/MEDLINE on scientific studies and publications on adverse effects and risks of different types of mouth–nose-covering masks according to the criteria mentioned above (see Figure 1: Review flowchart). Terms searched were "face masks", "surgical mask" and "N95" in combination with the terms "risk" and "adverse effects" as well as "side effects". The selection criteria of the papers were based on our above definition of risk and adverse effect of masks. Mainly English- and German-language publications of evidence levels I to III according to the recommendations of the Agency for Healthcare Research and Quality (AHQR) that were not older than 20 years at the time of the review were considered. The evaluation also excluded level IV evidence, such as case reports and irrelevant letters to the editor that exclusively reflect opinions without scientific evidence.

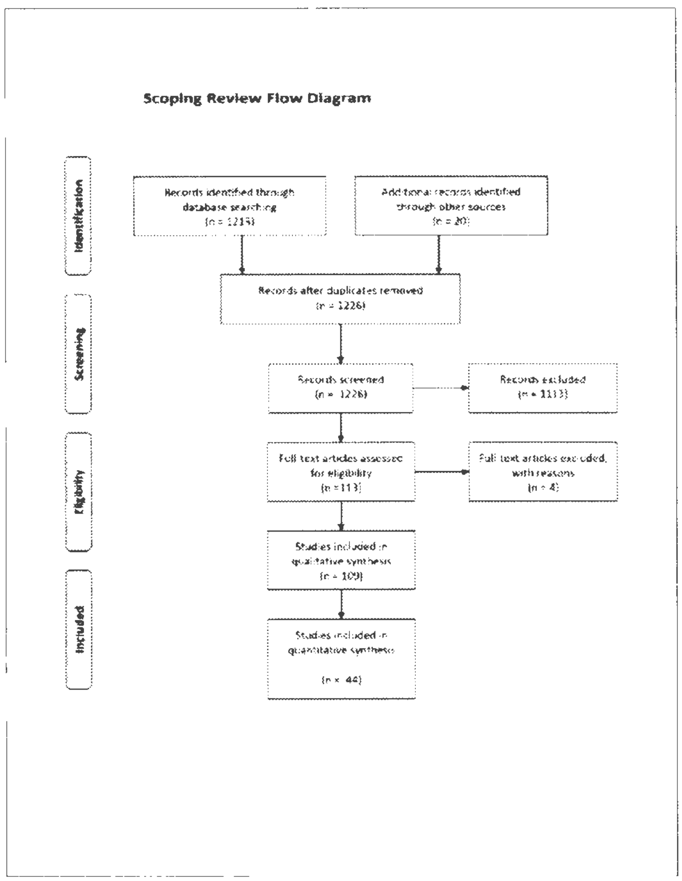

Figure 1. Scoping review flow diagram according to the PRISMA scheme.

After excluding 1113 papers that were irrelevant to the research question and did not meet the criteria mentioned (quantifiable, negative effects of masks, description of symptoms or the negative effects of masks), a total of 109 relevant publications were found for evaluation in the context of our scoping review (see Figure 1: Flow chart).

Sixty-five relevant publications concerning masks were considered being within the scope of the content-related evaluation. These included 14 reviews and 2 meta-analyses from the primary research. For the quantitative evaluation, 44 presentations of nega-

tive effects from the years 2004 to 2020 were eligible. Thirty-one of these studies were experimental (70%), and 13 studies were data collection studies in the sense of simple observational studies, especially in the dermatological field (30%). The observed study parameters and significant results from these 44 publications ($p < 0.05$ or $n \geq 50\%$) were compiled in an overall display (Figure 2). Based on this data, a correlation analysis of the observed mask effects was performed. This included a correlation calculation of the recorded symptoms and physiological changes (for nominally scaled, dichotomous variables according to Fisher using R, R Foundation for Statistical Computing, Vienna, Austria, version 4.0.2).

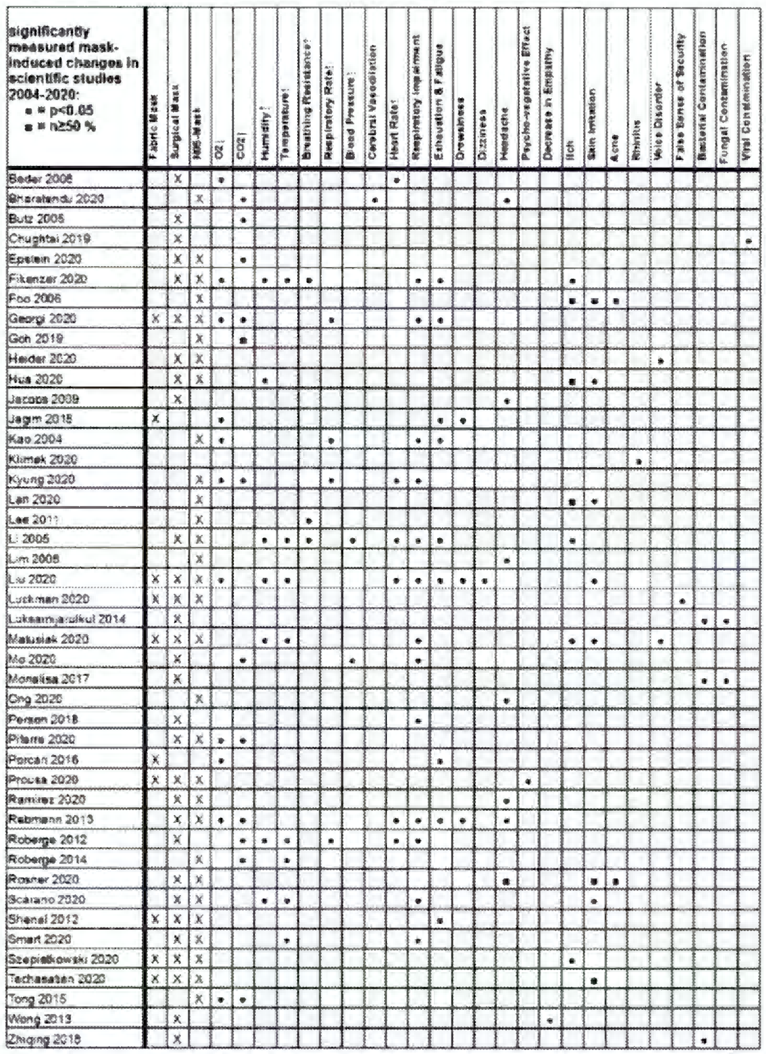

Figure 2. Overview including all 44 considered studies with quantified, significant adverse effects of masks (black dots and black rectangles). Not all studies examined each mentioned parameter, as focused or subject-related questions were often in the foreground. Gray fields correspond to a lack of coverage in the primary studies, white fields represent measured effects. We found an often combination of significant chemical, physical, physiological parameters and complaints. Drowsiness summarizes the symptom for any qualitative neurological deficits described in the scientific literature examined.

In addition, another 64 publications with a neighboring range of topics were consulted in connection with the mask effects we found. These included declarations, guidelines

and legal principles. In order to expand the amount of data for the discussion, we proceeded according to the "snowball principle" by locating citations of selected papers in the bibliographies and including them where appropriate.

Since the findings from the topics presented for discussion were to an unexpected degree subject-related, we decided to divide the results according to the fields of medicine. Of course, there are overlaps between the respective fields, which we point out in detail.

3. Results

A total of 65 scientific papers on masks qualified for a purely content-based evaluation. These included 14 reviews and two meta-analyses.

Of the mathematically evaluable, groundbreaking 44 papers with significant negative mask effects ($p < 0.05$ or $n \geq 50\%$), 22 were published in 2020 (50%), and 22 were published before the COVID-19 pandemic. Of these 44 publications, 31 (70%) were of experimental nature, and the remainder were observational studies (30%). Most of the publications in question were English (98%). Thirty papers referred to surgical masks (68%), 30 publications related to N95 masks (68%), and only 10 studies pertained to fabric masks (23%).

Despite the differences between the primary studies, we were able to demonstrate a statistically significant correlation in the quantitative analysis between the negative side effects of blood-oxygen depletion and fatigue in mask wearers with $p = 0.0454$.

In addition, we found a mathematically grouped common appearance of statistically significant confirmed effects of masks in the primary studies ($p < 0.05$ and $n \geq 50\%$) as shown in Figure 2. In nine of the 11 scientific papers (82%), we found a combined onset of N95 respiratory protection and carbon dioxide rise when wearing a mask. We found a similar result for the decrease in oxygen saturation and respiratory impairment with synchronous evidence in six of the nine relevant studies (67%). N95 masks were associated with headaches in six of the 10 studies (60%). For oxygen deprivation under N95 respiratory protectors, we found a common occurrence in eight of 11 primary studies (72%). Skin temperature rise under masks was associated with fatigue in 50% (three out of six primary studies). The dual occurrence of the physical parameter temperature rise and respiratory impairment was found in seven of the eight studies (88%). A combined occurrence of the physical parameters temperature rise and humidity/moisture under the mask was found in 100% within six of six studies, with significant readings of these parameters (Figure 2).

The literature review confirms that relevant, undesired medical, organ and organ system-related phenomena accompanied by wearing masks occur in the fields of internal medicine (at least 11 publications, Section 3.2). The list covers neurology (seven publications, Section 3.3), psychology (more than 10 publications, Section 3.4), psychiatry (three publications, Section 3.5), gynecology (three publications, Section 3.6), dermatology (at least 10 publications, Section 3.7), ENT medicine (four publications, Section 3.8), dentistry (one publication, Section 3.8), sports medicine (four publications, Section 3.9), sociology (more than five publications, Section 3.10), occupational medicine (more than 14 publications, Section 3.11), microbiology (at least four publications, Section 3.12), epidemiology (more than 16 publications, Section 3.13), and pediatrics (four publications, Section 3.14) as well as environmental medicine (four publications, Section 3.15).

We will present the general physiological effects as a basis for all disciplines. This will be followed by a description of the results from the different medical fields of expertise and closing off with pediatrics the final paragraph.

3.1. General Physiological and Pathophysiological Effects for the Wearer

As early as 2005, an experimental dissertation (randomized crossover study) demonstrated that wearing surgical masks in healthy medical personnel (15 subjects, 18–40 years old) leads to measurable physical effects with elevated transcutaneous carbon dioxide values after 30 min [13]. The role of dead space volume and CO_2 retention as a cause of the significant change ($p < 0.05$) in blood gases on the way to hypercapnia, which was still

within the limits, was discussed in this article. Masks expand the natural dead space (nose, throat, trachea, bronchi) outwards and beyond the mouth and nose.

An experimental increase in the dead space volume during breathing increases carbon dioxide (CO_2) retention at rest and under exertion and correspondingly the carbon dioxide partial pressure pCO_2 in the blood ($p < 0.05$) [14].

As well as addressing the increased rebreathing of carbon dioxide (CO_2) due to the dead space, scientists also debate the influence of the increased breathing resistance when using masks [15–17].

According to the scientific data, mask wearers as a whole show a striking frequency of typical, measurable, physiological changes associated with masks.

In a recent intervention study conducted on eight subjects, measurements of the gas content for oxygen (measured in O_2 Vol%) and carbon dioxide (measured in CO_2 ppm) in the air under a mask showed a lower oxygen availability even at rest than without a mask. A Multi-Rae gas analyzer was used for the measurements (RaeSystems®) (Sunnyvale, California CA, United States). At the time of the study, the device was the most advanced portable multivariant real-time gas analyzer. It is also used in rescue medicine and operational emergencies. The absolute concentration of oxygen (O_2 Vol%) in the air under the masks was significantly lower (minus 12.4 Vol% O_2 in absolute terms, statistically significant with $p < 0.001$) at 18.3% compared to 20.9% room air concentration. Simultaneously, a health-critical value of carbon dioxide concentration (CO_2 Vol%) increased by a factor of 30 compared to normal room air was measured (ppm with mask versus 464 ppm without mask, statistically significant with $p < 0.001$) [18].

These phenomena are responsible for a statistically significant increase in carbon dioxide (CO_2) blood content in mask wearers [19,20], on the one hand, measured transcutaneously via an increased $PtcCO_2$ value [15,17,19,21,22], on the other hand, via end-expiratory partial pressure of carbon dioxide ($PETCO_2$) [23,24] or, respectively, the arterial partial pressure of carbon dioxide ($PaCO_2$) [25].

In addition to the increase in the wearer's blood carbon dioxide (CO_2) levels ($p < 0.05$) [13,15,17,19,21–28], another consequence of masks that has often been experimentally proven is a statistically significant drop in blood oxygen saturation (SpO_2) ($p < 0.05$) [18,19,21,23,29–34]. A drop in blood oxygen partial pressure (PaO_2) with the effect of an accompanying increase in heart rate ($p < 0.05$) [15,23,29,30,34] as well as an increase in respiratory rate ($p < 0.05$) [15,21,23,35,36] have been proven.

A statistically significant measurable increase in pulse rate ($p < 0.05$) and decrease in oxygen saturation SpO_2 after the first ($p < 0.01$) and second hour ($p < 0.0001$) under a disposable mask (surgical mask) were reported by researchers in a mask intervention study they conducted on 53 employed neurosurgeons [30].

In another experimental study (comparative study), surgical and N95 masks caused a significant increase in heart rate ($p < 0.01$) as well as a corresponding feeling of exhaustion ($p < 0.05$). These symptoms were accompanied by a sensation of heat ($p < 0.0001$) and itching ($p < 0.01$) due to moisture penetration of the masks ($p < 0.0001$) in 10 healthy volunteers of both sexes after only 90 min of physical activity [35]. Moisture penetration was determined via sensors by evaluating logs (SCXI-1461, National Instruments, Austin, TX, USA).

These phenomena were reproduced in another experiment on 20 healthy subjects wearing surgical masks. The masked subjects showed statistically significant increases in heart rate ($p < 0.001$) and respiratory rate ($p < 0.02$) accompanied by a significant measurable increase in transcutaneous carbon dioxide $PtcCO_2$ ($p < 0.0006$). They also complained of breathing difficulties during the exercise [15].

The increased rebreathing of carbon dioxide (CO_2) from the enlarged dead space volume in mask wearers can reflectively trigger increased respiratory activity with increased muscular work as well as the resulting additional oxygen demand and oxygen consumption [17]. This is a reaction to pathological changes in the sense of an adaptation effect. A mask-induced drop in blood oxygen saturation value (SpO_2) [30] or the blood

oxygen partial pressure (PaO_2) [34] can in turn additionally intensify subjective chest complaints [25,34].

The documented mask-induced changes in blood gases towards hypercapnia (increased carbon dioxide/CO_2 blood levels) and hypoxia (decreased oxygen/O_2 blood levels) may result in additional nonphysical effects such as confusion, decreased thinking ability and disorientation [23,36–39], including overall impaired cognitive abilities and decrease in psychomotoric abilities [19,32,38–41]. This highlights the importance of changes in blood gas parameters (O_2 and CO_2) as a cause of clinically relevant psychological and neurological effects. The above parameters and effects (oxygen saturation, carbon dioxide content, cognitive abilities) were measured in a study on saturation sensors (Semi-Tec AG, Therwil, Switzerland), using a Borg Rating Scale, Frank Scale, Roberge Respirator Comfort Scale and Roberge Subjective Symptoms-during-Work Scale, as well as with a Likert scale [19]. In the other main study, conventional ECG, capnography and symptom questionnaires were used in measuring carbon dioxide levels, pulse and cognitive abilities [23]. Other physiological data collection was done with pulse oximeters (Allegiance, MCGaw, USA), subjective complaints were assessed with a 5-point Likert scale and motoric speed was recorded with linear-position transducers (Tendo-Fitrodyne, Sport Machins, Trencin, Slovakia) [32]. Some researchers used standardized, anonymized questionnaires to collect data on subjective complaints associated with masks [37].

In an experimental setting with different mask types (community, surgical, N95) a significant increase in heart rate ($p < 0.04$), a decrease in oxygen saturation SpO_2 ($p < 0.05$) with an increase in skin temperature under the mask (face) and difficulty of breathing ($p < 0.002$) were recorded in 12 healthy young subjects (students). In addition, the investigators observed dizziness ($p < 0.03$), listlessness ($p < 0.05$), impaired thinking ($p < 0.03$) and concentration problems ($p < 0.02$), which were also statistically significant when wearing masks [29].

According to other researchers and their publications, masks also interfere with temperature regulation, impair the field of vision and of non-verbal and verbal communication [15,17,19,36,37,42–45].

The above-mentioned measurable and qualitative physiological effects of masks can have implications in various areas of expertise in medicine.

It is known from pathology that not only supra-threshold stimuli exceeding normal limits have disease-relevant consequences. Subthreshold stimuli are also capable of causing pathological changes if the exposure time is long enough. Examples occur from the slightest air pollution by hydrogen sulfide resulting in respiratory problems (throat irritation, coughing, reduced absorption of oxygen) and neurological diseases (headaches, dizziness) [46]. Furthermore, subthreshold but prolonged exposure to nitrogen oxides and particulate matter is associated with an increased risk of asthma, hospitalization and higher overall mortality [47,48]. Low concentrations of pesticides are also associated with disease-relevant consequences for humans such as mutations, development of cancer and neurological disorders [49]. Likewise, the chronic subthreshold intake of arsenic is associated with an increased risk of cancer [50], subthreshold intake of cadmium with the promotion of heart failure [51], subthreshold intake of lead is associated with hypertension, renal metabolic disorders and cognitive impairment [52] or subthreshold intake of mercury with immune deficiency and neurological disorders [53]. Subliminal UV radiation exposure over long periods is also known to cause mutation-promoting carcinogenic effects (especially white skin cancer) [54].

The mask-induced adverse changes are relatively minor at first glance, but repeated exposure over longer periods in accordance with the above-mentioned pathogenetic principle is relevant. Long-term disease-relevant consequences of masks are to be expected. Insofar, the statistically significant results found in the studies with mathematically tangible differences between mask wearers and people without masks are clinically relevant. They give an indication that with correspondingly repeated and prolonged exposure to physical, chemical, biological, physiological and psychological conditions, some of which are

subliminal, but which are significantly shifted towards pathological areas, health-reducing changes and clinical pictures can develop such as high blood pressure and arteriosclerosis, including coronary heart disease (metabolic syndrome) as well as neurological diseases. For small increases in carbon dioxide in the inhaled air, this disease-promoting effect has been proven with the creation of headaches, irritation of the respiratory tract up to asthma as well as an increase in blood pressure and heart rate with vascular damage and, finally, neuropathological and cardiovascular consequences [38]. Even slightly but persistently increased heart rates encourage oxidative stress with endothelial dysfunction, via increased inflammatory messengers, and finally, the stimulation of arteriosclerosis of the blood vessels has been proven [55]. A similar effect with the stimulation of high blood pressure, cardiac dysfunction and damage to blood vessels supplying the brain is suggested for slightly increased breathing rates over long periods [56,57]. Masks are responsible for the aforementioned physiological changes with rises in inhaled carbon dioxide [18–28], small sustained increases in heart rate [15,23,29,30,35] and mild but sustained increases in respiratory rates [15,21,23,34,36].

For a better understanding of the side effects and dangers of masks presented in this literature review, it is possible to refer to well-known principles of respiratory physiology (Figure 3).

The average dead space volume during breathing in adults is approximately 150–180 mL and is significantly increased when wearing a mask covering the mouth and nose [58]. With an N95 mask, for example, the dead space volume of approximately 98–168 mL was determined in an experimental study [59]. This corresponds to a mask-related dead space increase of approximately 65 to 112% for adults and, thus, almost a doubling. At a respiratory rate of 12 per minute, the pendulum volume respiration with such a mask would, thus, be at least 2.9–3.8 L per minute. Therefore, the dead space amassed by the mask causes a relative reduction in the gas exchange volume available to the lungs per breath by 37% [60]. This largely explains the impairment of respiratory physiology reported in our work and the resulting side effects of all types of masks in everyday use in healthy and sick people (increase in respiratory rate, increase in heart rate, decrease in oxygen saturation, increase in carbon dioxide partial pressure, fatigue, headaches, dizziness, impaired thinking, etc.) [36,58].

In addition to the effect of increased dead space volume breathing, however, mask-related breathing resistance is also of exceptional importance (Figure 3) [23,36].

Experiments show an increase in airway resistance by a remarkable 126% on inhalation and 122% on exhalation with an N95 mask [60]. Experimental studies have also shown that moisturization of the mask (N95) increases the breathing resistance by a further 3% [61] and can, thus, increase the airway resistance up to 2.3 times the normal value.

This clearly shows the importance of the airway resistance of a mask. Here, the mask acts as a disturbance factor in breathing and makes the observed compensatory reactions with an increase in breathing frequency and simultaneous feeling of breathlessness plausible (increased work of the respiratory muscles). This extra strain due to the amplified work of breathing against bigger resistance caused by the masks also leads to intensified exhaustion with a rise in heart rate and increased CO_2 production. Fittingly, in our review of the studies on side effects of masks (Figure 2), we also found a percentage clustering of significant respiratory impairment and a significant drop in oxygen saturation (in about 75% of all study results).

In the evaluation of the primary papers, we also determined a statically significant correlation of the drop in oxygen saturation (SpO_2) and fatigue with a common occurrence in 58% of the mask use studies with significant results (Figure 2, $p < 0.05$).

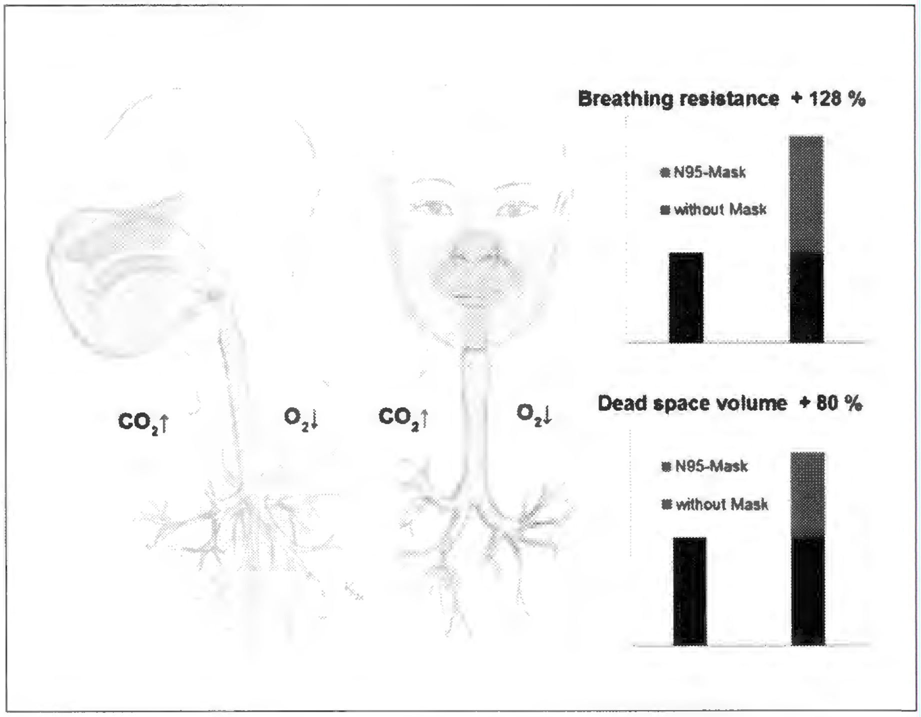

Figure 3. Pathophysiology of the mask (important physical and chemical effects): Illustration of the breathing resistance* and of the dead space volume of an N95 mask in an adult. When breathing, there is an overall significantly reduced possible gas exchange volume of the lungs of minus 37% caused by the mask (Lee 2011) [60] according to a decrease in breathing depth and volume due to the greater breathing resistance of plus128%* (exertion when inhaling greater than when exhaling) and due to the increased dead space volume of plus80%**, which does not participate directly in the gas exchange and is being only partially mixed with the environment. (* = averaged inspiration and expiration according to Lee 2011 [60] including moisture penetration according to Roberge 2010 [61], ** = averaged values according to Xu 2015 [59]).

3.2. Internistic Side Effects and Dangers

As early as 2012, an experiment showed that walking in the 20 masked subjects compared to the identical activity without masks significantly increased heart rates (average +9.4 beats per minute, $p < 0.001$) and breathing rates ($p < 0.02$). These physiological changes were accompanied by transcutaneous significantly measurable increased transcutaneous carbon dioxide ($PtcCO_2$) levels ($p < 0.0006$) as well as respiratory difficulties in the mask wearers compared to the control group [15].

In a recent experimental comparative study from 2020, 12 healthy volunteers under surgical masks as well as under N95 masks experienced measurable impairments in the measured lung function parameters as well as cardiopulmonary capacity (lower maximum blood lactate response) during moderate to heavy physical exertion compared to exertion without masks ($p < 0.001$) [31]. The mask-induced increased airway resistance led to increased respiratory work with increased oxygen consumption and demand, both of the respiratory muscles and the heart. Breathing was significantly impeded ($p < 0.001$) and participants reported mild pain. The scientists concluded from their results that the cardiac compensation of the pulmonary, mask-induced restrictions, which still functioned in healthy people, was probably no longer possible in patients with reduced cardiac output [31].

In another recent study, researchers tested fabric masks (community masks), surgical masks and FFP2/N95 masks in 26 healthy people during exercise on a cycle ergometer. All

masks also showed a measurable carbon dioxide (CO_2) retention ($PtcCO_2$) (statistically significant with $p < 0.001$) and, for N95 masks, a decrease in the oxygen saturation value SpO_2 (statistically significant at 75 and 100 W with $p < 0.02$ and $p < 0.005$, respectively). The clinical relevance of these changes was shown in an increase in breathing frequency with fabric masks ($p < 0.04$) as well as in the occurrence of the previously described mask-specific complaints such as a feeling of heat, shortness of breath and headaches. The stress perception was recorded on a Borg scale from 1 to 20. During physical exertion under an N95 mask, the group with masks showed a significant increase in the feeling of exhaustion compared to the group without with 14.6 versus 11.9 on the scale of 20. During the exposure, 14 of the 24 subjects wearing masks complained of shortness of breath (58%), four of headaches and two of a feeling of heat. Most of the complaints concerned FFP2 masks (72%) [21].

The aforementioned physiological and subjective physical effects of masks on healthy people at rest and under exertion [21,31] give an indication of the effect of masks on sick and elderly people even without exertion.

In an observational study of ten 20 to 50 year-old nurses wearing N95 masks during their shift work, side effects such as breathing difficulties ("I can't breathe"), feelings of exhaustion, headache ($p < 0.001$), drowsiness ($p < 0.001$) and a decrease in oxygen saturation SpO_2 ($p < 0.05$) as well as an increase in heart rate ($p < 0.001$) were statistically significant in association with an increase in obesity (BMI) [19]. The occurrence of symptoms under masks was also associated with older age (statistically significant correlation of fatigue and drowsiness with $p < 0.01$ each, nausea with $p < 0.05$, an increase in blood pressure with $p < 0.01$, headache with $p < 0.05$, breathing difficulties with $p < 0.001$) [19].

In an intervention study involving 97 patients with advanced chronic obstructive pulmonary disease (COPD) the respiratory rate, oxygen saturation and exhaled carbon dioxide equivalents (capnometry) changed unfavorably and significantly after the use of N95 masks (FFP2 equivalent) with an initial 10-minute rest and subsequent 6-minute walking. Seven patients discontinued the experiment due to serious complaints with a decrease in the oxygen saturation value SpO_2 and a pathological carbon dioxide (CO_2) retention as well as increased end-expiratory partial pressure of carbon dioxide ($PETCO_2$) [23]. In two patients, the $PETCO_2$ exceeded the normal limits and reached values of >50 mmHg. An FEV1 < 30% and a modified Medical Research Council (mMRC) Dyspnea Scale Score of ≥ 3, both indicators of advanced COPD, correlated with mask intolerance overall in this study. The most common symptom under mask was breathlessness at 86%. In the dropouts of the study, dizziness (57%) and headaches were also often recorded. In the mask-tolerant COPD patients, significant increases in heart rate, respiratory rate and end-expiratory carbon dioxide partial pressure $PETCO_2$ could be objectified even at rest, after only 10 min of mask-wearing ($p < 0.001$), accompanied by a decrease in oxygen saturation SpO_2 ($p < 0.001$) [23]. The results of this study with an evidence level IIa are indicative for COPD mask wearers.

In another retrospective comparative study on COPD and surgical masks, examiners were able to demonstrate statistically an increase in arterial partial pressure of carbon dioxide ($PaCO_2$) of approximately +8 mmHg ($p < 0.005$) and a concomitant mask-related increase in systolic blood pressure of +11 mmHg ($p < 0.02$) [25]. This increase is relevant in hypertensive patients, but also in healthy people with borderline blood pressure values as pathological value range triggered by mask-wearing can be induced.

In 39 hemodialysis patients with end-stage renal disease, a type N95 mask (FFP2 equivalent) caused a significant drop in blood oxygen partial pressure (PaO_2) in 70% of patients at rest (on hemodialysis) within only 4 h ($p = 0.006$). Despite a compensatory increased respiratory rate ($p < 0.001$), malaise with chest pain occurred ($p < 0.001$) and even resulted in hypoxemia (drop in oxygen below the normal limit) in 19% of the subjects [34]. The researchers concluded from their findings that elderly or patients with reduced cardiopulmonary function have a higher risk of developing a severe respiratory failure while wearing a mask [34].

In a review paper on the risks and benefits of masks worn during the COVID-19 crisis, other authors provide an equally critical assessment of mandatory mask use for patients with pneumonia, both with and without COVID-19 pneumonia disease [16].

3.3. Neurological Side Effects and Dangers

In a scientific evaluation of syncope in the operating theatre, 36 of 77 affected persons (47%) were associated with wearing a mask [62]. However, other factors could not be ruled out as contributory causes.

In their level III evidence review, neurologists from Israel, the UK and the USA state that a mask is unsuitable for epileptics because it can trigger hyperventilation [63]. The use of a mask significantly increases the respiratory rate by about plus 15 to 20% [15,21,23,34,64]. However, an increase in breathing frequency leading to hyperventilation is known to be used for provocation in the diagnosis of epilepsy and causes seizure-equivalent EEG changes in 80% of patients with generalized epilepsy and in up to 28% of focal epileptics [65].

Physicians from New York studied the effects of wearing masks of the surgical-type mask and N95 among medical personnel in a sample of 343 participants (surveyed using standardized, anonymized questionnaires). Wearing the masks caused detectable physical adverse effects such as impaired cognition (24% of wearers) and headaches in 71.4% of the participants. Of these, 28% persisted and required medication. Headache occurred in 15.2% under 1 h of wear, in 30.6% after 1 h of wear and in 29.7% after 3 h of wear. Thus, the effect intensified with increasing wearing time [37].

Confusion, disorientation and even drowsiness (Likert scale questionnaire) and reduced motoric abilities (measured with a linear position transducer) with reduced reactivity and overall impaired performance (measured with the Roberge Subjective Symptoms-during-Work Scale) as a result of mask use have also been documented in other studies [19,23,29,32,36,37].

The scientists explain these neurological impairments with a mask-induced latent drop in blood gas oxygen levels O_2 (towards hypoxia) or a latent increase in blood gas carbon dioxide levels CO_2 (towards hypercapnia) [36]. In view of the scientific data, this connection also appears to be indisputable [38–41].

In a mask experiment from 2020, significant impaired thinking ($p < 0.03$) and impaired concentration ($p < 0.02$) were found for all mask types used (fabric, surgical and N95 masks) after only 100 min of wearing the mask [29]. The thought disorders correlated significantly with a drop in oxygen saturation ($p < 0.001$) during mask use.

Initial headaches ($p < 0.05$) were experienced by up to 82% of 158, 21–35 year-old mask wearers in another study of N95 respiratory protection with one third (34%) experiencing headaches up to four times daily. Participants wore the mask for 18.3 days over a 30-day period with a mean of 5.9 h per day [66].

Significantly increased headache ($p < 0.05$) could be observed not only for N95 but also for surgical masks in participants of another observational study of health care workers [67].

In another study, the researchers classified 306 users with an average age of 43 years and wearing different types of masks, of whom 51% had an initial headache as a specific symptom related exclusively to increased surgical and N95 mask use (1 to 4 h, $p = 0.008$) [68].

Researchers from Singapore were able to demonstrate in a trial involving 154 healthy N95 health service mask wearers that a significant increase in mask-induced blood carbon dioxide levels (measured by end-expiratory partial pressure of carbon dioxide $PETCO_2$) and a measurably greater vasodilatation with an increase in cerebral artery flow in the cerebri media resulted. This was associated with headaches in the trial group ($p < 0.001$) [27].

According to the researchers, the aforementioned changes also contribute to headaches during the prolonged use of masks with a shift towards hypoxia and hypercapnia. Furthermore, stress and mechanical factors such as the irritation of cervical nerves in the neck and head area caused by the tight mask straps pressuring the nerve strands also contribute to headaches [66].

In the analysis of the primary studies, we were able to detect an association between the N95 mask and headaches. In six out of 10 studies, the significant headache appeared in conjunction with the N95 mask (60% of all studies, Figure 2).

3.4. Psychological Side Effects and Dangers

According to an experimental study, wearing surgical masks and N95 masks can also lead to a reduced quality of life owing to reduced cardiopulmonary capacity [31]. Masks, along with causing physiological changes and discomfort with progressive length of use, can also lead to significant discomfort ($p < 0.03$ to $p < 0.0001$) and a feeling of exhaustion ($p < 0.05$ to 0.0001) [69].

Besides the shift in blood gases towards hypercapnia (increase in CO_2) and hypoxia (decrease in O_2), detailed under general physiological effects (Section 3.1), masks also restrict the cognitive abilities of the individual (measured using a Likert scale survey) accompanied by a decline in psycho-motoric abilities and consequently a reduced responsiveness (measured using a linear position transducer) as well as an overall reduced performance capability (measured with the Roberge Subjective Symptoms-during-Work Scale) [29,32,38,39,41].

The mask also causes an impaired field of vision (especially affecting the ground and obstacles on the ground) and also presents an inhibition to habitual actions such as eating, drinking, touching, scratching and cleaning the otherwise uncovered part of the face, which is consciously and subconsciously perceived as a permanent disturbance, obstruction and restriction [36]. Wearing masks, thus, entails a feeling of deprivation of freedom and loss of autonomy and self-determination, which can lead to suppressed anger and subconscious constant distraction, especially as the wearing of masks is mostly dictated and ordered by others [70,71]. These perceived interferences of integrity, self-determination and autonomy, coupled with discomfort, often contribute to substantial distraction and may ultimately be combined with the physiologically mask-related decline in psycho-motoric abilities, reduced responsiveness and an overall impaired cognitive performance. It leads to misjudging situations as well as delayed, incorrect and inappropriate behavior and a decline in the effectiveness of the mask wearer [36,37,39–41].

The use of masks for several hours often causes further detectable adverse effects such as headaches, local acne, mask-associated skin irritation, itching, sensations of heat and dampness, impairments and discomfort predominantly affecting the head and face [19,29,35–37,71–73]. However, the head and face are significant for well-being due to their large representation in the sensitive cerebral cortex (homunculus) [36].

According to a questionnaire survey, masks also frequently cause anxiety and psycho-vegetative stress reactions in children—as well as in adults—with an increase in psychosomatic and stress-related illnesses and depressive self-experience, reduced participation, social withdrawal and lowered health-related self-care [74]. Over 50% of the mask wearers studied had at least mild depressive feelings [74]. Additional fear-inducing and often exaggerated media coverage can further intensify this. A recent retrospective analysis of the general media in the context of the 2014 Ebola epidemic showed a scientific truth content of only 38% of all publicly published information [75]. Researchers classified a total of 28% of the information as provocative and polarizing and 42% as exaggerating risks. In addition, 72% of the media content aimed to stir up health-related negative feelings. The feeling of fear, combined with insecurity and the primal human need to belong [76], causes a social dynamic that seems partly unfounded from a medical and scientific point of view.

The mask, which originally served purely hygienic purpose, has been transformed into a symbol of conformity and pseudo-solidarity. The WHO, for example, lists the advantages of the use of masks by healthy people in public to include a potentially reduced stigmatization of mask wearers, a sense of contribution to preventing the spread of the virus and a reminder to comply with other measures [2].

3.5. Psychiatric Side Effects and Dangers

As explained earlier, masks can cause increased rebreathing with an accumulation of carbon dioxide in the wearer due to increased dead space volume [16–18,20] (Figure 3), with often statistically significant measurable elevated blood carbon dioxide (CO2) levels in sufferers [13,15,17,19–28] (Figure 2). However, changes that lead to hypercapnia are known to trigger panic attacks [77,78]. This makes the significantly measurable increase in CO_2 caused by wearing a mask clinically relevant.

Interestingly, breath provocation tests by inhaling CO_2 are used to differentiate anxiety states in panic disorders and premenstrual dysphoria from other psychiatric clinical pictures. Here, absolute concentrations of 5% CO_2 already suffice to trigger panic reactions within 15–16 min [77]. The normal exhaled air content of CO_2 is about 4%.

It is obvious from experimental studies on masked subjects that concentration changes in the respiratory gases in the above-mentioned range with values above 4% could occur during rebreathing with prolonged mask use [18,23].

The activation of the locus coeruleus by CO_2 is used to generate panic reactions via respiratory gases [78,79]. This is because the locus coeruleus is an important part of the system of vegetative noradrenergic neurons, a control center in the brainstem, which reacts to an appropriate stimulus and changes in the gas concentrations in the blood by releasing the stress hormone noradrenaline [78].

From the physiological, neurological and psychological side effects and dangers described above (Sections 3.1, 3.3 and 3.4), additional problems can be derived for the use of masks in psychiatric cases. People undergoing treatment for dementia, paranoid schizophrenia, personality disorders with anxiety and panic attacks, but also panic disorders with claustrophobic components, are difficult to reconcile with a mask requirement, because even small increases in CO_2 can cause and intensify panic attacks [44,77–79].

According to a psychiatric study, patients with moderate to severe dementia have no understanding of COVID-19 protection measures and have to be persuaded to wear masks constantly [80].

According to a comparative study, patients with schizophrenia have a lower acceptance of mask-wearing (54.9% agreement) than ordinary practice patients (61.6%) [81]. The extent to which mask-wearing can lead to an exacerbation of schizophrenia symptoms has not yet been researched in detail.

When wearing masks, confusion, impaired thinking, disorientation (standardized recording via special rating and Likert scales, $p < 0.05$) and in some cases a decrease in maximum speed and reaction time (measured with the linear-position transducer, $p < 0.05$) were observed [19,32,36,38–41]. Psychotropic drugs reduce psycho-motoric functions in psychiatric patients. This can become clinically relevant especially with regard to the further reduced ability to react and the additional increased susceptibility to accidents of such patients when wearing masks.

In order to avoid an unintentional CO_2-triggered anesthesia [39], fixed and medically sedated patients, without the possibility of continuous monitoring, should not be masked according to the criteria of the Centers for Disease Control and Prevention, USA (CDC). This is because of the possible CO_2 retention described above, as there is a risk of unconsciousness, aspiration and asphyxia [16,17,20,38,82,83].

3.6. Gynaecological Side Effects and Dangers

As a critical variable, a low blood carbon dioxide level in pregnant women is maintained via an increased respiratory minute volume, stimulated by progesterone [22]. For a pregnant woman and her unborn child, there is a metabolic need for a fetal–maternal carbon dioxide (CO_2) gradient. The mother's blood carbon dioxide level should always be lower than that of the unborn child in order to ensure the diffusion of CO_2 from the fetal blood into the maternal circulation via the placenta.

Therefore, mask-related phenomena described above (Sections 3.1 and 3.2), such as the measurable changes in respiratory physiology with increased breathing resistance,

increased dead space volume (Figure 3) and the retention of exhaled carbon dioxide (CO_2) are of importance. If CO_2 is increasingly rebreathed under masks, this manifestation could, even with subliminal carbon dioxide increases, act as a disturbing variable of the fetal–maternal CO_2 gradient increasing over time of exposure and, thus, develop clinical relevance, also with regard to a reduced compensation reserve of the expectant mothers [20,22,28].

In a comparative study, 22 pregnant women wearing N95 masks during 20 min of exercise showed significantly higher percutaneous CO_2 values, with average $PtcCO_2$ values of 33.3 mmHg compared to 31.3 mmHg than in 22 pregnant women without masks ($p = 0.04$) [22]. The heat sensation of the expectant mothers was also significantly increased with masks, with $p < 0.001$ [22].

Accordingly, in another intervention study, researchers demonstrated that breathing through an N95 mask (FFP2 equivalent) impeded gas exchange in 20 pregnant women at rest and during exercise, causing additional stress on their metabolic system [28]. Thus, under an N95 mask, 20 pregnant women showed a decrease in oxygen uptake capacity VO_2 of about 14% (statistically significant, $p = 0.013$) and a decrease in carbon dioxide output capacity VCO_2 of about 18% (statistically significant, $p = 0.001$). Corresponding significant changes in exhaled oxygen and carbon dioxide equivalents were also documented with increases in exhaled carbon dioxide ($FeCO_2$) ($p < 0.001$) and decreases in exhaled oxygen (FeO_2) ($p < 0.001$), which were explained by an altered metabolism due to respiratory mask obstruction [28].

In experiments with predominantly short mask application times, neither the mothers nor the fetuses showed statistically significant increases in heart rates or changes in respiratory rates and oxygen saturation values. However, the exact effects of prolonged mask use in pregnant women remain unclear overall. Therefore, in pregnant women, extended use of surgical and N95 masks is viewed critically [20].

In addition, it is unclear whether the substances contained in industrially manufactured masks that can be inhaled over longer periods of time (e.g., formaldehyde as an ingredient of the textile and thiram as an ingredient of the ear bands) are teratogenic [20,84].

3.7. Dermatological Side Effects and Dangers

Unlike garments worn over closed skin, masks cover body areas close to the mouth and nose, i.e., body parts that are involved with respiration.

Inevitably, this leads not only to a measurable temperature rise [15,44,85], but also to a severe increase in humidity due to condensation of the exhaled air, which in turn changes the natural skin milieu considerably of perioral and perinasal areas [36,61,82]. It also increases the redness, pH-value, fluid loss through the skin epithelium, increased hydration and sebum production measurably [73]. Preexisting skin diseases are not only perpetuated by these changes, but also exacerbated. In general, the skin becomes more susceptible to infections and acne.

The authors of an experimental study were able to prove a disturbed barrier function of the skin after only 4 h of wearing a mask in 20 healthy volunteers, both for surgical masks and for N95 masks [73]. In addition, germs (bacteria, fungi and viruses) accumulate on the outside and inside of the masks due to the warm and moist environment [86–89]. They can cause clinically relevant fungal, bacterial or viral infections. The unusual increase in the detection of rhinoviruses in the sentinel studies of the German Robert Koch Institute (RKI) from 2020 [90] could be another indication of this phenomenon.

In addition, a region of the skin that is not evolutionarily adapted to such stimuli is subjected to increased mechanical stress. All in all, the above-mentioned facts cause the unfavorable dermatological effects with mask related adverse skin reactions like acne, rashes on the face and itch symptoms [91].

A Chinese research group reported skin irritation and itching when using N95 masks among 542 test participants and also a correlation between the skin damage that occurred and the time of exposure (68.9% at $\leq$6 h/day and 81.7% at >6 h/day) [92].

A New York study evaluated in a random sample of 343 participants the effects of frequent wearing of surgical mask type and N95 masks among healthcare workers during the COVID-19 pandemic. Wearing the masks caused headache in 71.4% of participants, in addition to drowsiness in 23.6%, detectable skin damage in 51% and acne in 53% of mask users [37].

On the one hand, direct mechanical skin lesions occur on the nose and cheekbones due to shear force, especially when masks are frequently put on and taken off [37,92].

On the other hand, masks create an unnaturally moist and warm local skin environment [29,36,82]. In fact, scientists were able to demonstrate a significant increase in humidity and temperature in the covered facial area in another study in which the test individuals wore masks for one hour [85]. The relative humidity under the masks was measured with a sensor (Atmo-Tube, San Francisco, CA, USA). The sensation of humidity and temperature in the facial area is more crucial for well-being than other body regions [36,44]. This can increase discomfort under the masks. In addition, the increase in temperature favors bacterial optimization.

The pressure of the masks also causes an obstruction of the flow physiology of lymph and blood vessels in the face, with the consequence of increased disturbance of skin function [73] and ultimately also contributing to acne in up to 53% of all wearers and other skin irritations in up to 51% of all wearers [36,37,82].

Other researchers examined 322 participants with N95 masks in an observational study and detected acne in up to 59.6% of them, itching in 51.4% and redness in 35.8% as side effects [72].

In up to 19.6% (273) of the 1393 wearers of different masks (community masks, surgical, N95 masks), itching could be objectified in one study, in 9% even severely. An atopic predisposition (allergy tendency) correlated with the risk of itching. The length of use was significantly related to the risk of itching ($p < 0.0001$) [93].

In another dermatological study from 2020, 96.9% of 876 users of all mask types (community masks, surgical masks, N95 masks) confirmed adverse problems with a significant increase in itching (7.7%), accompanied by fogging-up of glasses (21.3%), flushing (21.3%), slurred speech (12.3%) and difficulty breathing (35.9%) ($p < 0.01$) [71].

Apart from an increased incidence of acne [37,72,91] under masks, contact eczema and urticaria [94] are generally described in connection with hypersensitivities to ingredients of the industrially manufactured masks (surgical mask and N95) such as formaldehyde (ingredient of the textile) and thiram (ingredient of the ear bands) [73,84]. The hazardous substance thiram, originally a pesticide and corrosive, is used in the rubber industry as a optimization accelerator. Formaldehyde is a biocide and carcinogen and is used as a disinfectant in the industry.

Even isolated permanent hyperpigmentation as a result of post-inflammatory or pigmented contact dermatitis has been described by dermatologists after prolonged mask use [72,91].

3.8. ENT and Dental Side Effects and Dangers

There are reports from dental communities about negative effects of masks and are accordingly titled "mask mouth" [95]. Provocation of gingivitis (inflammation of the gums), halitosis (bad breath), candidiasis (fungal infestation of the mucous membranes with Candida albicans) and cheilitis (inflammation of the lips), especially of the corners of the mouth, and even plaque and caries are attributed to the excessive and improper use of masks. The main trigger of the oral diseases mentioned is an increased dry mouth due to a reduced saliva flow and increased breathing through the open mouth under the mask. Mouth breathing causes surface dehydration and reduced salivary flow rate (SFR) [95]. Dry mouth is scientifically proven due to mask wear [29]. The bad habit of breathing through the open mouth while wearing a mask seems plausible because such breathing pattern compensates for the increased breathing resistance, especially when inhaling through the masks [60,61]. In turn, the outer skin moisture [71,73,85] with altered

skin flora, which has already been described under dermatological side effects (Section 3.7), is held responsible as an explanation for the inflammation of the lips and corners of the mouth (cheilitis) [95]. This clearly shows the disease-promoting reversal of the natural conditions caused by masks. The physiological internal moisture with external dryness in the oral cavity converts into internal dryness with external moisture.

ENT physicians recently discovered a new form of irritant rhinitis due to N95 mask use in 46 patients. They performed endoscopies and nasal irrigations on mask wearers, which were subsequently assessed pathologically. Clinical problems were recorded with standardized questionnaires. They found statistically significant evidence of mask-induced rhinitis and itching and swelling of the mucous membranes as well as increased sneezing ($p < 0.01$). Endoscopically, it showed an increased secretion and evidence of inhaled mask polypropylene fibers as the trigger of mucosal irritation [96].

In a study of 221 health care workers, ENT physicians objectified a voice disorder in 33% of mask users. The VHI-10 score of 1 to 10, which measures voice disorders, was on average 5.72 higher in these mask users (statistically significant with $p < 0.001$). The mask not only acted as an acoustic filter, provoking excessively loud speech, it also seems to trigger impaired vocal cord coordination because the mask compromises the pressure gradients required for undisturbed speech [43]. The researchers concluded from their findings that masks could pose a potential risk of triggering new voice disorders as well as exacerbating existing ones.

3.9. Sports Medicine Side Effects and Dangers

According to the literature, performance-enhancing effects of masks regarding cardiovascular optimization and improvement of oxygen uptake capacity cannot be proven.

For example, in an experimental reference study (12 subjects per group), the training mask that supposedly mimics altitude training (ETM: elevation training mask) only had training effects on the respiratory muscles. However, mask wearers showed significantly lower oxygen saturation values (SpO_2%) during exercise (SpO_2 of 94% for mask wearers versus 96% for mask-less, $p < 0.05$) [33], which can be explained by an increased dead space volume and increased resistance during breathing. The measured oxygen saturation values were significantly lower than the normal values in the group of mask wearers, which indicates a clinical relevance.

The proven adaptation effect of the respiratory muscles in healthy athletes [33] clearly suggests that masks have a disruptive effect on respiratory physiology.

In another intervention study on mask use in weightlifters, researchers documented statistically significant effects of reduced attention (questionnaire recording, Likert scale) and a slowed maximum speed of movement detectable by means of sensors (both significant at $p < 0.001$), leading the researchers to conclude that mask use in sport is not without risks. As a secondary finding, they also detected a significant decrease in oxygen saturation SpO_2 when performing special weight-lifting exercises ("back squats") in the mask group after only 1 min of exercise compared to the mask-free group ($p < 0.001$) [32]. The proven tendency of the masks to shift the chemical parameter oxygen saturation SpO_2 in a pathological direction (lower limit value 95%) may well have clinical relevance in untrained or sick individuals.

Sports medicine confirmed an increase in carbon dioxide (CO_2) retention, with an elevation in CO_2 partial pressure in the blood with larger respiratory dead space volumes [14].

In fact, dead space-induced CO_2 retention while wearing a mask during exercise was also experimentally proven. The effects of a short aerobic exercise under N95 masks were tested on 16 healthy volunteers. A significantly increased end-expiratory partial pressure of carbon dioxide ($PETCO_2$) with plus 8 mmHg ($p < 0.001$) was found [24]. The increase in blood carbon dioxide (CO_2) in the mask wearers under maximum load was plus 14% CO_2 for surgical masks and plus 23% CO_2 for N95 masks, an effect that may well have clinical relevance in the pre-diseased, elderly and children, as these values strongly approached the pathological range [24].

In an interesting endurance study with eight middle-aged subjects (19–66), the gas content for O_2 and CO_2 under the masks was determined before and after exercise. Even at rest, the oxygen availability under the masks was 13% lower than without the masks and the carbon dioxide (CO_2) concentration was 30 times higher. Under stress (Ruffier test), the oxygen concentration (% O_2) below the mask dropped significantly by a further 3.7%, while the carbon dioxide concentration (% CO_2) increased significantly by a further 20% (statistically significant with $p < 0.001$). Correspondingly, the oxygen saturation of the blood (SpO_2) of the test persons also decreased significantly from 97.6 to 92.1% ($p < 0.02$) [18]. The drop in the oxygen saturation value (SpO_2) to 92%, clearly below the normal limit of 95%, is to be classified as clinically relevant and detrimental to health.

These facts are an indication that the use of masks also triggers the effects described above leading to hypoxia and hypercapnia in sports. Accordingly, the WHO and Centers for Disease Control and Prevention, GA, USA (CDC) advise against wearing masks during physical exercise [82,97].

3.10. Social and Sociological Side Effects and Dangers

The results of a Chilean study with health care workers show that masks act like an acoustic filter and provoke excessively loud speech. This causes a voice disorder [43]. The increased volume of speech also contributes to increased aerosol production by the mask wearer [98]. These experimental data measured with the Aerodynamic Particle Sizer (APS, TSI, model 332, TSI Incorporated, Minnesota, MI, USA) are highly relevant.

Moreover, mask wearers are prevented from interacting normally in everyday life due to impaired clarity of speech [45], which tempts them to get closer to each other.

This results in a distorted prioritization in the general public, which counteracts the recommended measures associated with the COVID-19 pandemic. The WHO prioritizes social distancing and hand hygiene with moderate evidence and recommends wearing a mask with weak evidence, especially in situations where individuals are unable to maintain a physical distance of at least 1 m [3].

The disruption of non-verbal communication due to the loss of facial expression recognition under the mask can increase feelings of insecurity, discouragement and numbness as well as isolation, which can be extremely stressful for the mentally and hearing-impaired [16].

Experts point out that masks disrupt the basics of human communication (verbal and nonverbal). The limited facial recognition caused by masks leads to a suppression of emotional signals. Masks, therefore, disrupt social interaction, erasing the positive effect of smiles and laughter but at the same time greatly increasing the likelihood of misunderstandings because negative emotions are also less evident under masks [42].

A decrease in empathy perception through mask use with disruption of the doctor–patient relationship has already been scientifically proven on the basis of a randomized study (statistically significant, with $p = 0.04$) [99]. In this study, the Consultation Empathy Care Measury, the Patient Enablement Instrument (PEI) Score and a Satisfaction Rating Scale were assessed in 1030 patients. The 516 doctors, who wore masks throughout, conveyed reduced empathy towards the patients and, thus, nullified the positive health-promoting effects of a dynamic relationship. These results demonstrate a disruption of interpersonal interaction and relationship dynamics caused by masks.

The WHO guidance on the use of masks in children in the community, published in August 2020, points out that the benefits of mask use in children must be weighed up against the potential harms, including social and communicational concerns [100].

Fears that widespread pandemic measures will lead to dysfunctional social life with degraded social, cultural and psychological interactions have also been expressed by other experts [6–8,42].

3.11. Social and Occupational Medicine Side Effects and Hazards

In addition to mask-specific complaints such as a feeling of heat, dampness, shortness of breath and headache, various physiological phenomena were documented, such as the significant increase in heart and respiratory rate, the impairment of lung function parameters, the decrease in cardiopulmonary capacity (e.g., lower maximum blood lactate response) [15,19,21,23,29–31], as well as the changes in oxygen and carbon dioxide both in the end-expiratory and the air under the mask that was measured in the blood of the individuals [13,15,18,19,21–25,27–34]. The significant changes were measurable after only a few minutes of wearing a mask and in some cases reached magnitudes of minus 13% reduced O_2 concentration and 30-fold increased CO_2 concentration of the inhaled air under masks ($p < 0.001$) [18]. The changes observed were not only statistically significant, but also clinically relevant; the subjects also showed pathological oxygen saturation after exposure to masks ($p < 0.02$) [18].

Shortness of breath during light exertion (6 min walking) under surgical masks has been recorded with statistical significance in 44 healthy subjects in a prospective experimental intervention study ($p < 0.001$) [101]. Here, the complaints were assessed using a subjective, visual analogue scale.

In another study from 2011, all tested masks caused a significantly measurable increase in discomfort and a feeling of exhaustion in the 27 subjects during prolonged usage ($p < 0.0001$) [69].

These symptoms lead to additional stress for the occupational mask wearer and, thus, in relation to the feeling of exhaustion, contribute to the self-perpetuating vicious circle caused by the vegetative sympathetic activation, which further increases the respiratory and heart rate, blood pressure and increased sense of exhaustion [16,20,35,83].

Other studies showed that the psychological and physical effects of the masks can lead to an additional reduction in work performance (measured with the Roberge Subjective Symptoms-during-Work Scale, a Likert scale of 1–5) via increased feelings of fatigue, dissatisfaction and anxiety [58,102,103].

Wearing masks over a longer period of time also led to physiological and psychological impairments in other studies and, thus, reduced work performance [19,36,58,69]. In experiments on respiratory-protective equipment, an increase in the dead space volume by 350 mL leads to a reduction in the possible performance time by approx. −19%, furthermore to a decrease in breathing comfort by −18% (measured via a subjective rating scale) [58]. In addition, the time spent working and the flow of work is interrupted and reduced by putting on and taking off the masks and changing them. The reduced work performance has been recorded in the literature found as described above (especially in Sections 3.1 and 3.2) but has not been quantified further in detail [36,58].

Surgical mask type and N95 protective equipment frequently caused adverse effects in medical personnel such as headaches, breathing difficulties, acne, skin irritation, itching, decreased alertness, decreased mental performance and feelings of dampness and heat [19,29,37,71,85]. Subjective, work performance-reducing, mask-related impairments in users, measured with special survey scores and Likert scales, have also been described in other studies [15,21,27,32,35,43,66–68,72,96,99].

In Section 3.7 on dermatology, we already mentioned a paper that demonstrated a significant temperature increase of 1.9 °C on average (to over 34.5 °C) in the mask-covered facial area ($p < 0.05$) [85]. Due to the relatively larger representation in the sensitive cerebral cortex (homunculus), the temperature sensation in the face is more decisive for the feeling of well-being than other body regions [36,44]. The perception of discomfort when wearing a mask can, thus, be intensified. Interestingly, in our analysis, we found a combined occurrence of the physical variable temperature rise under the mask and the symptom respiratory impairment in seven of eight studies concerned, with a mutual significantly measured occurrence in 88%. We also detected a combined occurrence of significantly measured temperature rise under the mask and significantly measured fatigue in 50% of the relevant primary studies (three of six papers, Figure 2). These clustered associations of

temperature rise with symptoms of respiratory impairment and fatigue suggest a clinical relevance of the detected temperature rise under masks. In the worst case scenario, the effects mentioned can reinforce each other and lead to decompensation, especially in the presence of COPD, heart failure and respiratory insufficiency.

The sum of the disturbances and discomforts that can be caused by a mask also contributes to distraction (see also psychological impairment). These, in conjunction with a decrease in psycho-motoric skills, reduced responsiveness and overall impaired cognitive performance (all of which are pathophysiological effects of wearing a mask) [19,29,32,39–41] can lead to a failure to recognize hazards and, thus, to accidents or avoidable errors at work [19,36,37]. Of particular note here are mask-induced listlessness ($p < 0.05$), impaired thinking ($p < 0.05$) and concentration problems ($p < 0.02$) as measured by a Likert scale (1–5) [29]. Accordingly, occupational health regulations take action against such scenarios. The German Industrial Accident Insurance (DGUV) has precise and extensive regulations for respiratory protective equipment where they document the limitation of wearing time, levels of work intensity and defined instruction obligation [104].

The standards and norms prescribed in many countries regarding different types of masks to protect their workers are also significant from an occupational health point of view [105]. In Germany, for example, there are very strict safety specifications for masks from other international countries. These specify the requirements for the protection of the wearer [106]. All these standards and the accompanying certification procedures were increasingly relaxed with the introduction of mandatory masks for the general public. This meant that non-certified masks such as community masks were also used on a large scale in the work and school sectors for longer periods during the pandemic measures [107]. Most recently, in October 2020, the German Social Accident Insurance (DGUV) recommended the same usage time limits for community masks as for filtering half masks, namely, a maximum of three shifts of 120 min per day with recovery breaks of 30 min in between. In Germany, FFP2 (N95) masks must be worn for 75 min, followed by a 30-minute break. An additional suitability examination by specialized physicians is also obligatory and stipulated for occupationally used respirators [104].

3.12. Microbiological Consequences for Wearer and Environment: Foreign/Self-Contamination

Masks cause retention of moisture [61]. Poor filtration performance and incorrect use of surgical masks and community masks, as well as their frequent reuse, imply an increased risk of infection [108–110]. The warm and humid environment created by and in masks without the presence of protective mechanisms such as antibodies, the complement system, defense cells and pathogen-inhibiting and on a mucous membrane paves the way for unimpeded growth and, thus, an ideal growth and breeding ground for various pathogens such as bacteria and fungi [88] and also allows viruses to accumulate [87]. The warm and humid mask microclimate favors the accumulation of various germs on and underneath the masks [86], and the germ density is measurably proportional to the length of time the mask is worn. After only 2 h of wearing the mask, the pathogen density increases almost tenfold in experimental observation studies [87,89].

From a microbiological and epidemiological point of view, masks in everyday use pose a risk of contamination. This can occur as foreign contamination but also as self-contamination. On the one hand, germs are sucked in or attach themselves to the masks through convection currents. On the other hand, potential infectious agents from the nasopharynx accumulate excessively on both the outside and inside of the mask during breathing [5,88]. This is compounded by contact with contaminated hands. Since masks are constantly penetrated by germ-containing breath and the pathogen reproduction rate is higher outside mucous membranes, potential infectious pathogens accumulate excessively on the outside and inside of masks. On and in the masks, there are quite serious, potentially disease-causing bacteria and fungi such as *E. coli* (54% of all germs detected), Staphylococcus aureus (25% of all germs detected), Candida (6%), Klebsiella (5%), Enterococci (4%),

Pseudomonads (3%), Enterobacter (2%) and Micrococcus (1%) even detectable in large quantities [88].

In another microbiological study, the bacterium Staphylococcus aureus (57% of all bacteria detected) and the fungus Aspergillus (31% of all fungi detected) were found to be the dominant germs on 230 surgical masks examined [86].

After more than six hours of use, the following viruses were found in descending order on 148 masks worn by medical personnel: adenovirus, bocavirus, respiratory syncytial virus and influenza viruses [87].

From this aspect, it is also problematic that moisture distributes these potential pathogens in the form of tiny droplets via capillary action on and in the mask, whereby further proliferation in the sense of self- and foreign contamination by the aerosols can then occur internally and externally with every breath [35]. In this regard, it is also known from the literature that masks are responsible for a proportionally disproportionate production of fine particles in the environment and, surprisingly, much more so than in people without masks [98].

It was shown that all mask-wearing subjects released significantly more smaller particles of size 0.3–0.5 μm into the air than mask-less people, both when breathing, speaking and coughing (fabric, surgical, N95 masks, measured with the Aerodynamic Particle Sizer, APS, TS, model 3329) [98]. The increase in the detection of rhinoviruses in the sentinel studies of the German RKI from 2020 [90] could be a further indication of this phenomenon, as masks were consistently used by the general population in public spaces in that year.

3.13. Epidemiological Consequences

The possible side effects and dangers of masks described in this paper are based on studies of different types of masks. These include the professional masks of the surgical mask type and N95/KN95 (FFP2 equivalent) that are commonly used in everyday life, but also the community fabric masks that were initially used. In the case of N95, the N stands for National Institute for Occupational Safety and Health of the United States (NIOSH), and 95 indicates the 95 per cent filtering capacity for fine particles up to at least 0.3 μm [82].

A major risk of mask use in the general public is the creation of a false sense of security with regard to protection against viral infections, especially in the sense of a falsely assumed strong self-protection. Disregarding infection risks may not only neglect aspects of source control, but also result in other disadvantages. Although there are quite a few professional positive accounts of the widespread use of masks in the general populace [111], most of the serious and evident scientific reports conclude that the general obligation to wear masks conveys a false sense of security [4,5]. However, this leads to a neglect of those measures that, according to the WHO, have a higher level of effectiveness than mask-wearing: social distancing and hand hygiene [2,112]. Researchers were able to provide statistically significant evidence of a false sense of security and more risky behavior when wearing masks in an experimental setting [112].

Decision makers in many countries informed their citizens early on in the pandemic in March 2020 that people without symptoms should not use a medical mask, as this created a false sense of security [113]. The recommendation was ultimately changed in many countries. At least Germany pointed out that wearers of certain types of masks such as the common fabric masks (community masks) cannot rely on them to protect them or others from transmission of SARS-CoV-2 [114].

However, scientists not only complain about the lack of evidence for fabric masks in the scope of a pandemic [16,110], but also about the high permeability of fabric masks with particles and the potential risk of infection they pose [108,109]. Ordinary fabric masks with a 97% penetration for particle dimensions of $\geq$0.3 μm are in stark contrast to medical-type surgical masks with a 44% penetration. In contrast, the N95 mask has a penetration rate of less than 0.01% for particles $\geq$ 0.3 μm in the laboratory experiment [108,115].

For the clinical setting in hospitals and outpatient clinics, the WHO guidelines recommend only surgical masks for influenza viruses for the entire patient treatment except for the strongly aerosol-generating measures, for which finer filtering masks of the type N95 are suggested. However, the WHO's endorsement of specific mask types is not entirely evidence-based due to the lack of high-quality studies in the health sector [108,109,116,117].

In a laboratory experiment (evidence level IIa study), it was demonstrated that both surgical masks and N95 masks have deficits in protection against SARS-CoV-2 and influenza viruses using virus-free aerosols [118]. In this study, the FFP2-equivalent N95 mask performed significantly better in protection (8–12 times more effective) than the surgical mask, but neither mask type established reliable, hypothesis-generated protection against corona and influenza viruses. Both mask types could be penetrated unhindered by aerosol particles with a diameter of 0.08 to 0.2 μm. Both the SARS-CoV-2 pathogens with a size of 0.06 to 0.14 μm [119] and the influenza viruses with 0.08 to 0.12 μm are unfortunately well below the mask pore sizes [118].

The filtering capacity of the N95 mask up to 0.3 μm [82] is usually not achieved by surgical masks and community masks. However, aerosol droplets, which have a diameter of 0.09 to 3 μm in size, are supposed to serve as a transport medium for viruses. These also penetrate the medical masks by 40%. Often, there is also a poor fit between the face and the mask, which further impairs their function and safety [120]. The accumulation of aerosol droplets on the mask is problematic. Not only do they absorb nanoparticles such as viruses [6], but they also follow the airflow when inhaling and exhaling, causing them to be carried further. In addition, a physical decay process has been described for aerosol droplets at increasing temperatures, as also occurs under a mask [15,44,85]. This process can lead to a decrease in size of the fine water droplets up to the diameter of a virus [121,122]. The masks filter larger aerosol droplets but cannot retain viruses themselves and such smaller, potentially virus-containing aerosol droplets of less than 0.2 μm and hence cannot stop the spread of virus [123].

Similarly, in an in vivo comparative studies of N95 and surgical masks, there were no significant differences in influenza virus infection rates [124,125]. Although this contrasts with encouraging in vitro laboratory results with virus-free aerosols under non-natural conditions, even with fabric masks [126], it should be noted that under natural in-vivo conditions, the promising filtration functions of fabric masks based on electrostatic effects also rapidly diminish under increasing humidity [127]. A Swiss textile lab test of various masks available on the market to the general public recently confirmed that most mask types filter aerosols insufficiently. For all but one of the eight reusable fabric mask types tested, the filtration efficacy according to EN149 was always less than 70% for particles of 1 μm in size. For disposable masks, only half of all eight mask types tested were efficient enough at filtering to retain 70% of particles 1 μm in size [128].

A recent experimental study even demonstrated that all mask-wearing people (surgical, N95, fabric masks) release significantly and proportionately smaller particles of size 0.3 to 0.5 μm into the air than mask-less people, both when breathing, speaking and coughing [98]. According to this, the masks act like nebulizers and contribute to the production of very fine aerosols. Smaller particles, however, spread faster and further than large ones for physical reasons. Of particular interest in this experimental reference study was the finding that a test subject wearing a single-layer fabric mask was also able to release a total of 384% more particles (of various sizes) when breathing than a person without [98].

It is not only the aforementioned functional weaknesses of the masks themselves that lead to problems, but also their use. This increases the risk of a false sense of security. According to the literature, mistakes are made by both healthcare workers and lay people when using masks as hygienically correct mask use is by no means intuitive. Overall, 65% of healthcare professionals and as many as 78% of the general population, use masks incorrectly [116]. With both surgical masks and N95 masks, adherence to the rules of use is impaired and not adequately followed due to reduced wearability with heat discomfort and skin irritation [29,35,116,129]. This is exacerbated by the accumulation of carbon dioxide

due to the dead space (especially under the N95 masks) with the resulting headaches described [19,27,37,66–68,83]. Increased heart rate, itching and feelings of dampness [15,29,30,35,71] also lead to reduced safety and quality during use (see also social and occupational health side effects and hazards). For this reason, (everyday) masks are even considered a general risk for infection in the general population, which does not come close to imitating the strict hygiene rules of hospitals and doctors' offices: the supposed safety, thus, becomes a safety risk itself [5].

In a meta-analysis of evidence level Ia commissioned by the WHO, no effect of masks in the context of influenza virus pandemic prevention could be demonstrated [130]. In 14 randomized controlled trials, no reduction in the transmission of laboratory-confirmed influenza infections was shown. Due to the similar size and distribution pathways of the virus species (influenza and Corona, see above), the data can also be transferred to SARS-CoV-2 [118]. Nevertheless, a combination of occasional mask-wearing with adequate hand-washing caused a slight reduction in infections for influenza in one study [131]. However, since no separation of hand hygiene and masks was achieved in this study, the protective effect can rather be attributed to hand hygiene in view of the aforementioned data [131].

A recently published large prospective Danish comparative study comparing mask wearers and non-mask wearers in terms of their infection rates with SARS-CoV2 could not demonstrate any statistically significant differences between the groups [132].

3.14. Paediatric Side Effects and Hazards

Children are particularly vulnerable and may be more likely to receive inappropriate treatment or additional harm. It can be assumed that the potential adverse mask effects described for adults are all the more valid for children (see Section 3.1 to Section 3.13: physiological internal, neurological, psychological, psychiatric, dermatological, ENT, dental, sociological, occupational and social medical, microbiological and epidemiological impairments and also Figures 2 and 3).

Special attention must be paid to the respiration of children, which represents a critical and vulnerable physiological variable due to higher oxygen demand, increased hypoxia susceptibility of the CNS, lower respiratory reserve, smaller airways with a stronger increase in resistance when the lumen is narrowed. The diving reflex caused by stimulating the nose and upper lip can cause respiratory arrest to bradycardia in the event of oxygen deficiency.

The masks currently used for children are exclusively adult masks manufactured in smaller geometric dimensions and had neither been specially tested nor approved for this purpose [133].

In an experimental British research study, the masks frequently led to feelings of heat ($p < 0.0001$) and breathing problems ($p < 0.03$) in 100 school children between 8 and 11 years of age especially during physical exertion, which is why the protective equipment was taken off by 24% of the children during physical activity [133]. The exclusion criteria for this mask experiment were lung disease, cardiovascular impairment and claustrophobia [133].

Scientists from Singapore were able to demonstrate in their level Ib study published in the renowned journal "nature" that 106 children aged between 7 and 14 years who wore FFP2 masks for only 5 min showed an increase in the inspiratory and expiratory CO_2 levels, indicating disturbed respiratory physiology [26].

However, a disturbed respiratory physiology in children can have long-term disease-relevant consequences. Slightly elevated CO_2 levels are known to increase heart rate, blood pressure, headache, fatigue and concentration disorders [38].

Accordingly, the following conditions were listed as exclusion criteria for mask use [26]: any cardiopulmonary disease including but not limited to: asthma, bronchitis, cystic fibrosis, congenital heart disease, emphysema; any condition that may be aggravated by physical exertion, including but not limited to: exercise-induced asthma; lower respiratory tract infections (pneumonia, bronchitis within the last 2 weeks), anxiety disorders,

diabetes, hypertension or epilepsy/attack disorder; any physical disability due to medical, orthopedic or neuromuscular disease; any acute upper respiratory illness or symptomatic rhinitis (nasal obstruction, runny nose or sneezing); any condition with deformity that affects the fit of the mask (e.g., increased facial hair, craniofacial deformities, etc.).

It is also important to emphasize the possible effects of masks in neurological diseases, as described earlier (Section 3.3).

Both masks and face shields caused fear in 46% of children (37 out of 80) in a scientific study. If children are given the choice of whether the doctor examining them should wear a mask they reject this in 49% of the cases. Along with their parents, the children prefer the practitioner to wear a face visor (statistically significant with $p < 0.0001$) [134].

A recent observational study of tens of thousands of mask-wearing children in Germany helped the investigators objectify complaints of headaches (53%), difficulty concentrating (50%), joylessness (49%), learning difficulties (38%) and fatigue in 37% of the 25,930 children evaluated. Of the children observed, 25% had new onset anxiety and even nightmares [135]. In children, the threat scenarios generated by the environment are further maintained via masks, in some cases, even further intensified, and in this way, existing stress is intensified (presence of subconscious fears) [16,35,136,137].

This can in turn lead to an increase in psychosomatic and stress-related illnesses [74,75]. For example, according to an evaluation, 60% of mask wearers showed stress levels of the highest grade 10 on a scale of 1 to a maximum of 10. Less than 10% of the mask wearers surveyed had a stress level lower than 8 out of a possible 10 [74].

As children are considered a special group, the WHO also issued a separate guideline on the use of masks in children in the community in August 2020, explicitly advising policy makers and national authorities, given the limited evidence, that the benefits of mask use in children must be weighed up against the potential harms associated with mask use. This includes feasibility and discomfort, as well as social and communication concerns [100].

According to experts, masks block the foundation of human communication and the exchange of emotions and not only hinder learning but deprive children of the positive effects of smiling, laughing and emotional mimicry [42]. The effectiveness of masks in children as a viral protection is controversial, and there is a lack of evidence for their widespread use in children; this is also addressed in more detail by the scientists of the German University of Bremen in their thesis paper 2.0 and 3.0 [138].

3.15. Effects on the Environment

According to WHO estimates of a demand of 89 million masks per month, their global production will continue to increase under the Corona pandemic [139]. Due to the composition of, e.g., disposable surgical masks with polymers such as polypropylene, polyurethane, polyacrylonitrile, polystyrene, polycarbonate, polyethylene and polyester [140], an increasing global challenge, also from an environmental point of view, can be expected, especially outside Europe, in the absence of recycling and disposal strategies [139]. The aforementioned single use polymers have been identified as a significant source of plastic and plastic particles for the pollution of all water cycles up to the marine environment [141].

A significant health hazard factor is contributed by mask waste in the form of microplastics after decomposition into the food chain. Likewise, contaminated macroscopic disposable mask waste—especially before microscopic decay—represents a widespread medium for microbes (protozoa, bacteria, viruses, fungi) in terms of invasive pathogens [86–89,142]. Proper disposal of bio-contaminated everyday mask material is insufficiently regulated even in western countries.

4. Discussion

The potential drastic and undesirable effects found in multidisciplinary areas illustrate the general scope of global decisions on masks in general public in the light of combating the pandemic. According to the literature found, there are clear, scientifically recorded adverse effects for the mask wearer, both on a psychological and on a social and physical level.

Neither higher level institutions such as the WHO or the European Centre for Disease Prevention and Control (ECDC) nor national ones, such as the Centers for Disease Control and Prevention, GA, USA (CDC) or the German RKI, substantiate with sound scientific data a positive effect of masks in the public (in terms of a reduced rate of spread of COVID-19 in the population) [2,4,5].

Contrary to the scientifically established standard of evidence-based medicine, national and international health authorities have issued their theoretical assessments on the masks in public places, even though the compulsory wearing of masks gives a deceptive feeling of safety [5,112,143].

From an infection epidemiological point of view, masks in everyday use offer the risk of self-contamination by the wearer from both inside and outside, including via contaminated hands [5,16,88]. In addition, masks are soaked by exhaled air, which potentially accumulates infectious agents from the nasopharynx and also from the ambient air on the outside and inside of the mask. In particular, serious infection-causing bacteria and fungi should be mentioned here [86,88,89], but also viruses [87]. The unusual increase in the detection of rhinoviruses in the sentinel studies of the German RKI from 2020 [90] could be an indication of this phenomenon. Clarification through further investigations would therefore be desirable.

Masks, when used by the general public, are considered by scientists to pose a risk of infection because the standardized hygiene rules of hospitals cannot be followed by the general public [5]. On top of that, mask wearers (surgical, N95, fabric masks) exhale relatively smaller particles (size 0.3 to 0.5 μm) than mask-less people and the louder speech under masks further amplifies this increased fine aerosol production by the mask wearer (nebulizer effect) [98].

The history of modern times shows that already in the influenza pandemics of 1918–1919, 1957–58, 1968, 2002, in SARS 2004–2005 as well as with the influenza in 2009, masks in everyday use could not achieve the hoped-for success in the fight against viral infection scenarios [67,144]. The experiences led to scientific studies describing as early as 2009 that masks do not show any significant effect with regard to viruses in an everyday scenario [129,145]. Even later, scientists and institutions rated the masks as unsuitable to protect the user safely from viral respiratory infections [137,146,147]. Even in hospital use, surgical masks lack strong evidence of protection against viruses [67].

Originally born out of the useful knowledge of protecting wounds from surgeons' breath and predominantly bacterial droplet contamination [144,148,149], the mask has been visibly misused with largely incorrect popular everyday use, particularly in Asia in recent years [150]. Significantly, the sociologist Beck described the mask as a cosmetic of risk as early as 1992 [151]. Unfortunately, the mask is inherent in a vicious circle: strictly speaking, it only protects symbolically and at the same time represents the fear of infection. This phenomenon is reinforced by the collective fear mongering, which is constantly nurtured by main stream media [137].

Nowadays, the mask represents a kind of psychological support for the general population during the virus pandemic, promising them additional anxiety-reduced freedom of movement. The recommendation to use masks in the sense of "source control" not out of self-protection but out of "altruism" [152] is also very popular with the regulators as well as the population of many countries. The WHO's recommendation of the mask in the current pandemic is not only a purely infectiological approach, but is also clear on the possible advantages for healthy people in the general public. In particular, a reduced potential stigmatization of mask wearers, the feeling of a contribution made to preventing the spread of the virus, as well as the reminder to adhere to other measures are mentioned [2].

It should not go unmentioned that very recent data suggest that the detection of SARS-CoV-2 infection does not seem to be directly related to popular mask use. The groups examined in a retrospective comparative study (infected with SARS-CoV-2 and not infected) did not differ in their habit of using masks: approximately 70% of the subjects in both groups always wore masks and another 14.4% of them frequently [143].

In a Danish prospective study on mask-wearing carried out on about 6000 participants and published in 2020, scientists found no statistically significant difference in the rates of SARS-CoV-2 infection when comparing the group of 3030 mask wearers with the 2994 mask-less participants in the study ($p = 0.38$) [132].

Indeed, in the case of viral infections, masks appear to be not only less effective than expected, but also not free of undesirable biological, chemical, physical and psychological side effects [67]. Accordingly, some experts claim that well-intentioned unprofessionalism can be quite dangerous [6].

The dermatological colleagues were the first to describe common adverse effects of mask-wearing in larger collectives. Simple, direct physical, chemical and biological effects of the masks with increases in temperature, humidity and mechanical irritation caused acne in up to 60% of wearers [37,71–73,85]. Other significantly documented consequences were eczema, skin damage and overall impaired skin barrier function [37,72,73].

These direct effects of mask use are an important pointer to further detrimental effects affecting other organ systems.

In our work, we have identified scientifically validated and numerous statistically significant adverse effects of masks in various fields of medicine, especially with regard to a disruptive influence on the highly complex process of breathing and negative effects on the respiratory physiology and gas metabolism of the body (see Figures 2 and 3). The respiratory physiology and gas exchange play a key role in maintaining a health-sustaining balance in the human body [136,153]. According to the studies we found, a dead space volume that is almost doubled by wearing a mask and a more than doubled breathing resistance (Figure 3) [59–61] lead to a rebreathing of carbon dioxide with every breathing cycle [16–18,39,83] with—in healthy people mostly—a subthreshold but, in sick people, a partly pathological increase in the carbon dioxide partial pressure ($PaCO_2$) in the blood [25,34,58]. According to the primary studies found, these changes contribute reflexively to an increase in respiratory frequency and depth [21,23,34,36] with a corresponding increase in the work of the respiratory muscles via physiological feedback mechanisms [31,36]. Thus, it is not, as initially assumed, purely positive training through mask use. This often increases the subliminal drop in oxygen saturation SpO_2 in the blood [23,28–30,32], which is already reduced by increased dead space volume and increased breathing resistance [18,31].

The overall possible resulting measurable drop in oxygen saturation O_2 of the blood on the one hand [18,23,28–30,32] and the increase in carbon dioxide (CO_2) on the other [13,15,19,21–28] contribute to an increased noradrenergic stress response, with heart rate increase [29,30,35] and respiratory rate increase [15,21,23,34], in some cases also to a significant blood pressure increase [25,35].

In panic-prone individuals, stress-inducing noradrenergic sympathetic activation can be partly directly mediated via the carbon dioxide (CO_2) mechanism at the locus coeruleus in the brainstem [39,78,79,153], but also in the usual way via chemo-sensitive neurons of the nucleus solitarius in the medulla [136,154]. The nucleus solitarius [136] is located in the deepest part of the brainstem, a gateway to neuronal respiratory and circulatory control [154]. A decreased oxygen (O_2) blood level there causes the activation of the sympathetic axis via chemoreceptors in the carotids [155,156].

Even subthreshold changes in blood gases such as those provoked when wearing a mask cause reactions in these control centers in the central nervous system. Masks, therefore, trigger direct reactions in important control centers of the affected brain via the slightest changes in oxygen and carbon dioxide in the blood of the wearer [136,154,155].

A link between disturbed breathing and cardiorespiratory diseases such as hypertension, sleep apnea and metabolic syndrome has been scientifically proven [56,57]. Interestingly, decreased oxygen/O_2 blood levels and also increased carbon dioxide/CO_2 blood levels are considered the main triggers for the sympathetic stress response [38,136]. The aforementioned chemo-sensitive neurons of the nucleus solitarius in the medulla are considered to be the main responsible control centers [136,154,155]. Clinical effects of prolonged mask-wearing would, thus, be a conceivable intensification of chronic stress re-

actions and negative influences on the metabolism leading towards a metabolic syndrome. The mask studies we found show that such disease-relevant respiratory gas changes (O_2 and CO_2) [38,136] are already achieved by wearing a mask [13,15,18,19,21–34].

A connection between hypoxia, sympathetic reactions and leptin release is scientifically known [136].

Additionally important is the connection of breathing with the influence on other bodily functions [56,57], including the psyche with the generation of positive emotions and drive [153]. The latest findings from neuro-psychobiological research indicate that respiration is not only a function regulated by physical variables to control them (feedback mechanism), but rather independently influences higher-level brain centers and, thus, also helps to shape psychological and other bodily functions and reactions [153,157,158]. Since masks impede the wearer's breathing and accelerate it, they work completely against the principles of health-promoting breathing [56,57] used in holistic medicine and yoga. According to recent research, undisturbed breathing is essential for happiness and healthy drive [157,159], but masks work against this.

The result of significant changes in blood gases in the direction of hypoxia (drop in oxygen saturation) and hypercapnia (increase in carbon dioxide concentration) through masks, thus, has the potential to have a clinically relevant influence on the human organism even without exceeding normal limits.

According to the latest scientific findings, blood-gas shifts towards hypoxia and hypercapnia not only have an influence on the described immediate, psychological and physiological reactions on a macroscopic and microscopic level, but additionally on gene expression and metabolism on a molecular cellular level in many different body cells. Through this, the drastic disruptive intervention of masks in the physiology of the body also becomes clear down to the cellular level, e.g., in the activation of hypoxia-induced factor (HIF) through both hypercapnia and hypoxia-like effects [160]. HIF is a transcription factor that regulates cellular oxygen supply and activates signaling pathways relevant to adaptive responses. e.g., HIF inhibits stem cells, promotes tumor cell growth and inflammatory processes [160]. Based on the hypoxia- and hypercapnia-promoting effects of masks, which have been comprehensively described for the first time in our study, potential disruptive influences down to the intracellular level (HIF-a) can be assumed, especially through the prolonged and excessive use of masks. Thus, in addition to the vegetative chronic stress reaction in mask wearers, which is channeled via brain centers, there is also likely to be an adverse influence on metabolism at the cellular level. With the prospect of continued mask use in everyday life, this also opens up an interesting field of research for the future.

The fact that prolonged exposure to latently elevated CO_2 levels and unfavorable breathing air compositions has disease-promoting effects was recognized early on. As early as 1983, the WHO described "Sick Building Syndrome" (SBS) as a condition in which people living indoors experienced acute disease-relevant effects that increased with time of their stay, without specific causes or diseases [161,162]. The syndrome affects people who spend most of their time indoors, often with subliminally elevated CO_2 levels, and are prone to symptoms such as increased heart rate, rise in blood pressure, headaches, fatigue and difficulty concentrating [38,162]. Some of the complaints described in the mask studies we found (Figure 2) are surprisingly similar to those of Sick Building Syndrome [161]. Temperature, carbon dioxide content of the air, headaches, dizziness, drowsiness and itching also play a role in Sick Building Syndrome. On the one hand, masks could themselves be responsible for effects such as those described for Sick Building Syndrome when used for a longer period of time. On the other hand, they could additionally intensify these effects when worn in air-conditioned buildings, especially when masks are mandatory indoors. Nevertheless, there was a tendency towards higher systolic blood pressure values in mask wearers in some studies [21,31,34], but statistical significance was only found in two studies [25,35]. However, we found more relevant and significant evidence of heart

rate increase, headache, fatigue and concentration problems associated with mask wearers (Figure 2) indicating the clinical relevance of wearing masks.

According to the scientific results and findings, masks have measurably harmful effects not only on healthy people, but also on sick people and their relevance is likely to increase with the duration of use [69]. Further research is needed here to shed light on the long-term consequences of widespread mask use with subthreshold hypoxia and hypercapnia in the general population, also regarding possible exacerbating effects on cardiorespiratory lifestyle diseases such as hypertension, sleep apnea and metabolic syndrome. The already often elevated blood carbon dioxide (CO_2) levels in overweight people, sleep apnea patients and patients with overlap-COPD could possibly increase even further with everyday masks. Not only a high body mass index (BMI) but also sleep apnea are associated with hypercapnia during the day in these patients (even without masks) [19,163]. For such patients, hypercapnia means an increase in the risk of serious diseases with increased morbidity, which could then be further increased by excessive mask use [18,38].

The hypercapnia-induced effects of sympathetic stress activation are even cycle phase-dependent in women. Controlled by a progesterone mechanism, the sympathetic reaction, measured by increased blood pressure in the luteal phase, is considerably stronger [164]. This may also result in different sensitivities for healthy and sick women to undesirable effects masks have, which are related to an increase in carbon dioxide (CO_2).

In our review, negative physical and psychological changes caused by masks could be objectified even in younger and healthy individuals.

The physical and chemical parameters did not exceed the normal values in most cases but were statistically significantly measurable ($p < 0.05$) tending towards pathological ranges. They were accompanied by physical impairments (see Figure 2). It is well known that subthreshold stimuli are capable of causing pathological changes when exposed to them for a long time: not only a single high dose of a disturbance, but also a chronically persistent, subthreshold exposure to it often leads to illness [38,46–48,50–54]. The scientifically repeatedly measurable physical and chemical mask effects were often accompanied by typical subjective complaints and pathophysiological phenomena. The fact that these frequently occur simultaneously and together indicates a syndrome under masks.

Figure 2 sums up the significant mask-dependent physiological, psychological, somatic and general pathological changes and their frequent occurrence together is striking. Within the framework of the quantitative evaluation of the experimental studies, we were actually able to prove a statistically significant correlation of the observed side effects of fatigue and oxygen depletion under mask use with $p < 0.05$. In addition, we found a frequent, simultaneous and joint occurrence of further undesirable effects in the scientific studies (Figure 2). Statistically significant associations of such co-occurring, adverse effects have already been described in primary studies [21,29]. We detected a combined occurrence of the physical parameter temperature rise under the mask with the symptom respiratory impairment in seven of the nine studies concerned (88%). We found a similar result for the decrease in oxygen saturation under mask and the symptom respiratory impairment with a simultaneous detection in six of the eight studies concerned (67%). We detected a combined occurrence of carbon dioxide rise under N95 mask use in nine of the 11 scientific papers (82%). We found a similar result for oxygen drop under N95 mask use with simultaneous co-occurrence in eight of 11 primary papers (72%). The use of N95 masks was also associated with headache in six of the 10 primary studies concerned (60%). A combined occurrence of the physical parameters temperature rise and humidity under masks was even found 100% within six of the six studies with significant measurements of these parameters (Figure 2).

Since the symptoms were described in combination in mask wearers and were not observed in isolation in the majority of cases, we refer to them as general Mask-Induced Exhaustion Syndrome (MIES) because of the consistent presentation in numerous papers from different disciplines. These include the following, predominantly statistically significantly

($p < 0.05$) proven pathophysiological changes and subjective complaints, which often occur in combination as described above (see also Section 3.1 to Section 3.11, Figures 2–4):

- Increase in dead space volume [22,24,58,59] (Figure 3, Sections 3.1 and 3.2).
- Increase in breathing resistance [31,35,61,118] (Figure 3, Figure 2: Column 8).
- Increase in blood carbon dioxide [13,15,19,21–28] (Figure 2: Column 5).
- Decrease in blood oxygen saturation [18,19,21,23,28–34] (Figure 2: Column 4).
- Increase in heart rate [15,19,23,29,30,35] (Figure 2: Column 12).
- Decrease in cardiopulmonary capacity [31] (Section 3.2).
- Feeling of exhaustion [15,19,21,29,31–35,69] (Figure 2: Column 14).
- Increase in respiratory rate [15,21,23,34] (Figure 2: Column 9).
- Difficulty breathing and shortness of breath [15,19,21,23,25,29,31,34,35,71,85,101,133] (Figure 2: Column 13).
- Headache [19,27,37,66–68,83] (Figure 2: Column 17).
- Dizziness [23,29] (Figure 2: Column 16).
- Feeling of dampness and heat [15,16,22,29,31,35,85,133] (Figure 2: Column 7).
- Drowsiness (qualitative neurological deficits) [19,29,32,36,37] (Figure 2: Column 15).
- Decrease in empathy perception [99] (Figure 2: Column 19).
- Impaired skin barrier function with acne, itching and skin lesions [37,72,73] (Figure 2: Column 20–22).

It can be deduced from the results that the effects described in healthy people are all more pronounced in sick people, since their compensatory mechanisms, depending on the severity of the illness, are reduced or even exhausted. Some existing studies on and with patients with measurable pathological effects of the masks support this assumption [19,23,25,34]. In most scientific studies, the exposure time to masks in the context of the measurements/investigations was significantly less (in relation to the total wearing and duration of use) than is expected of the general public under the current pandemic regulations and ordinances.

The exposure time limits are little observed or knowingly disregarded in many areas today as already mentioned in Section 3.11 on occupational medicine. The above facts allow the conclusion that the described negative effects of masks, especially in some of our patients and the very elderly, may well be more severe and adverse with prolonged use than presented in some mask studies.

From a doctor's viewpoint, it may also be difficult to advise children and adults who, due to social pressure (to wear a mask) and the desire to feel they belong, suppress their own needs and concerns until the effects of masks have a noticeable negative impact on their health [76]. Nevertheless, the use of masks should be stopped immediately at the latest when shortness of breath, dizziness or vertigo occur [23,25]. From this aspect, it seems sensible for decision makers and authorities to provide information, to define instruction obligations and offer appropriate training for employers, teachers and other persons who have a supervisory or caregiving duty. Knowledge about first aid measures could also be refreshed and expanded accordingly in this regard.

Elderly, high-risk patients with lung disease, cardiac patients, pregnant women or stroke patients are advised to consult a physician to discuss the safety of an N95 mask as their lung volume or cardiopulmonary performance may be reduced [23]. A correlation between age and the occurrence of the aforementioned symptoms while wearing a mask has been statistically proven [19]. Patients with reduced cardiopulmonary function are at increased risk of developing serious respiratory failure with mask use according to the referenced literature [34]. Without the possibility of continuous medical monitoring, it can be concluded that they should not wear masks without close monitoring. The American Asthma and Allergy Society has already advised caution in the use of masks with regard to the COVID-19 pandemic for people with moderate and severe lung disease [165]. Since the severely overweight, sleep apnea patients and overlap-COPD sufferers are known to be prone to hypercapnia, they also represent a risk group for serious adverse health effects under extensive mask use [163]. This is because the potential of masks to produce additional

CO_2 retention may not only have a disruptive effect on the blood gases and respiratory physiology of sufferers, but may also lead to further serious adverse health effects in the long term. Interestingly, in an animal experiment an increase in CO_2 with hypercapnia leads to contraction of smooth airway muscles with constriction of bronchi [166]. This effect could explain the observed pulmonary decompensations of patients with lung disease under masks (Section 3.2) [23,34].

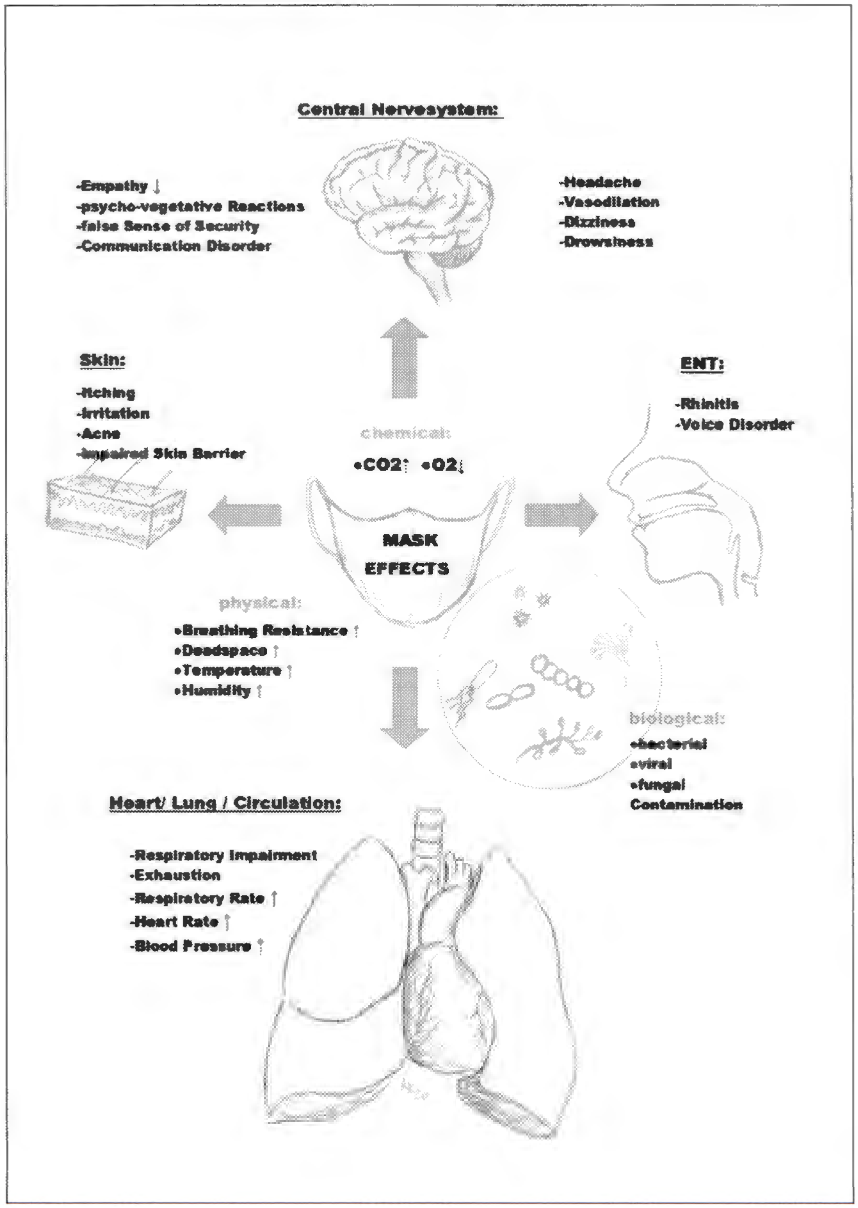

Figure 4. Unfavorable mask effects as components of Mask-Induced Exhaustion Syndrome (MIES). The chemical, physical and biological effects, as well as the organ system consequences mentioned, are all documented with statistically significant results in the scientific literature found (Figure 2). The term drowsiness is used here to summarize any qualitative neurological deficits described in the examined scientific literature.

Patients with renal insufficiency requiring dialysis are, according to the literature available, further candidates for a possible exemption from the mask requirement [34].

According to the criteria of the Centers for Disease Control and Prevention, GA, USA (CDC), sick and helpless people who cannot remove a mask on their own should be exempted from the mask requirement [82].

Since it can be assumed that children react even more sensitively to masks, the literature suggests that masks are a contraindication for children with epilepsies (hyperventilation as a trigger for seizures) [63]. In the field of pediatrics, special attention should also be paid to the mask symptoms described under psychological, psychiatric and sociological effects with possible triggering of panic attacks by CO_2 rebreathing in the case of predisposition and also reinforcement of claustrophobic fears [77–79,167]. The mask-related disturbance of verbal [43,45,71] and non-verbal communication and, thus, of social interaction is particularly serious for children. Masks restrict social interaction and block positive perceptions (smiling and laughing) and emotional mimicry [42]. The proven mask-induced mild to moderate cognitive impairment with impaired thinking, decreased attention and dizziness [19,23,29,32,36,37,39–41,69], as well as the psychological and neurological effects [135], should be additionally taken into account when masks are compulsory at school and in the vicinity of both public and non-public transport, also regarding the possibility of an increased risk of accidents (see also occupational health side effects and hazards) [19,29,32,36,37]. The exclusion criteria mentioned in pediatric studies on masks (see pediatric impairments, Section 3.14) [26,133] should also apply to an exclusion of these children from the general mask obligation in accordance with the scientific findings for the protection of the sick children concerned. The long-term sociological, psychological and educational consequences of a comprehensive masking requirement extended to schools are also unpredictable with regard to the psychological and physical development of healthy children [42,135]. Interestingly, according to the Corona Thesis Paper of the University of Bremen children "are infected less often, they become ill less often, the lethality is close to zero, and they also pass on the infection less often", according to the Thesis Paper 2.0 of the German University of Bremen on page 6 [138]. Studies conducted under real-life conditions with outcome endpoints showing hardly any infections, hardly any morbidity, hardly any mortality and only low contagiousness in children are clearly in the majority, according to Thesis Paper 3.0 of the German University of Bremen [138]. A recent German observational study (5600 reporting pediatricians) also showed a surprisingly low incidence of COVID-19 disease in children [168]. The infection of adults with SARS-CoV-2 by children has been considered in only one suspected case, but could not be proven with certainty, since the parents also had numerous contacts and exposure factors for viral infections due to their occupation. In this case, the circulating headlines in the public media that children contribute more to the incidence of infection are to be regarded as anecdotal.

In pregnant women, the use of masks during exertion or at rest over long periods of time is to be regarded as critical as little research has been done on this [20]. If there is clear scientific evidence of increased dead space ventilation with possible accumulation of CO_2 in the mother's blood, the use of masks by pregnant women for more than 1 h, as well as under physical stress, should be avoided in order to protect the unborn child [20,22]. The hypercapnia-promoting masks could act as a confounder of the fetal/maternal CO_2 gradient in this case (Section 3.6) [20,22,28].

According to the literature cited in the Section 3.5 on psychiatric side effects (personality disorders with anxiety and panic attacks, claustrophobia, dementia and schizophrenia), masking should only be done, if at all, with careful consideration of the advantages and disadvantages. Attention should be paid to possible provocation of the number and severity of panic attacks [77–79].

In patients with headaches, a worsening of symptoms can be expected with prolonged mask use (see also Section 3.3., neurological side effects) [27,66–68]. As a result of the increase in blood carbon dioxide (CO_2) when the mask is used, vasodilatation occurs in the central nervous system and the pulsation of the blood vessels decreases [27]. In this connection, it is also interesting to note radiological experiments that demonstrate an increase in brain volume under subthreshold, but still within normal limits of CO_2 increase

in the blood by means of structural MRI. The blood carbon dioxide increase was produced in seven subjects via rebreathing with resulting median carbon dioxide concentration of 42 mmHg and an interquartile range of 39.44 mmHg, corresponding to only a subthreshold increase given the normal values of 32–45 mmHg. In the experiment, there was a significant increase in brain parenchymal volume measurable under increased arterial CO_2 levels ($p < 0.02$), with a concomitant decrease in CSF spaces ($p < 0.04$), entirely in accordance with the Monroe–Kelly doctrine, according to which the total volume within the skull always remains the same. The authors interpreted the increase in brain volume as an expression of an increase in blood volume due to a CO_2 increase-induced dilation of the cerebral vessels [169]. The consequences of such equally subthreshold carbon dioxide (CO_2) increases even under masks [13,15,18,19,22,23,25] are unclear for people with pathological changes inside the skull (aneurysms, tumors, etc.) with associated vascular changes [27] and brain volume shifts [169] especially due to longer exposure while wearing a mask, but could be of great relevance due to the blood gas-related volume shifts that take place.

In view of the increased dead space volume, the long-term and increased accumulation and rebreathing of other respiratory air components apart from CO_2 is also unexplained, both in children and in old and sick people. Exhaled air contains over 250 substances, including irritant or toxic gases such as nitrogen oxides (NO), hydrogen sulfide (H2S), isoprene and acetone [170]. For nitrogen oxides [47] and hydrogen sulfide [46], pathological effects relevant to disease have been described in environmental medicine even at a low but chronic exposure [46–48]. Among the volatile organic compounds in exhaled air, acetone and isoprene dominate in terms of quantity, but allyl methyl sulfide, propionic acid and ethanol (some of bacterial origin) should also be mentioned [171]. Whether such substances also react chemically with each other underneath masks and in the dead space volume created by masks (Figure 3), and with the mask tissue itself, and in what quantities these and possible reaction products are rebreathed, has not yet been clarified. In addition to the blood gas changes described above (O_2 drop and CO_2 rise), these effects could also play a role with regard to undesirable mask effects. Further research is needed here and is of particular interest in the case of prolonged and ubiquitous use of masks.

The WHO sees the integration of individual companies and communities that produce their own fabric masks as a potential social and economic benefit. Due to the global shortage of surgical masks and personal protective equipment, it sees this as a source of income and points out that the reuse of fabric masks can reduce costs and waste and contribute to sustainability [2]. In addition to the question of certification procedures for such fabric masks, it should also be mentioned that due to the extensive mask obligation, textile (artificial) substances in the form of micro- and nanoparticles, some of which cannot be degraded in the body, are chronically absorbed into the body through inhalation to an unusual extent. In the case of medical masks, disposable polymers such as polypropylene, polyurethane, polyacrylonitrile, polystyrene, polycarbonate, polyethylene and polyester should be mentioned [140]. ENT physicians have already been able to detect such particles in the nasal mucosa of mask wearers with mucosal reactions in the sense of a foreign body reaction with rhinitis [96]. In the case of community masks, other substances from the textile industry are likely to be added to those mentioned above. The body will try to absorb these substances through macrophages and scavenger cells in the respiratory tract and alveoli as part of a foreign body reaction, whereby toxin release and corresponding local and generalized reactions may occur in an unsuccessful attempt to break them down [172]. Extensive respiratory protection in permanent long-term use (24/7), at least from a theoretical point of view, also potentially carries the risk of leading to a mask-related pulmonary [47] or even generalized disorder, as is already known from textile workers chronically exposed to organic dusts in the Third World (byssinosis) [172].

For the general public, from a scientific angle, it is necessary to draw on the long-standing knowledge of respiratory protection in occupational medicine in order to protect children in particular from harm caused by uncertified masks and improper use.

The universal undefined and extended mask requirement—without taking into account multiple predispositions and susceptibilities—contradicts the claim of an increasingly important individualized medicine with a focus on the unique characteristics of each individual [173].

A systematic review on the topic of masks is necessary according to the results of our scoping review. The primary studies often showed weaknesses in operationalization, especially in the evaluation of cognitive and neuropsychological parameters. Computerized test procedures will be useful here in the future. Mask research should also set itself the future goal of investigating and defining subgroups for whom respiratory protection use is particularly risky.

5. Limitations

Our approach with a focus on negative effects is in line with Villalonga-Olives and Kawachi [12]. With the help of such selective questioning in the sense of dialectics, new insights can be gained that might otherwise have remained hidden. Our literature search focused on adverse negative effects of masks, in particular to point out risks especially for certain patient groups. Therefore, publications presenting only positive effects of masks were not considered in this review.

For a compilation of studies with harmless results when using masks, reference must, therefore, be made to reviews with a different research objective, whereby attention must be paid to possible conflicts of interest there. Some of the studies excluded by us lacking negative effects have shown methodological weaknesses (small, non-uniform experimental groups, missing control group even without masks due to corona constraints, etc.) [174]. In other words, if no negative concomitant effects were described in publications, it does not necessarily mean that masks have exclusively positive effects. It is quite possible that negative effects were simply not mentioned in the literature and the number of negative effects may well be higher than our review suggests.

We only searched one database, so the number of papers on negative mask effects may be higher than we reported.

In order to be able to describe characteristic effects for each mask type even more extensively, we did not have enough scientific data on the respective special designs of the masks. There is still a great need for research in this area due to the current pandemic situation with extensive mandatory masking.

In addition, the experiments evaluated in this paper do not always have uniform measurement parameters and study variables and, depending on the study, take into account the effect of masks at rest or under stress with subjects having different health conditions. Figure 2, therefore, represents a compromise. The results of the primary studies on mask use partially showed no natural variation in parameters, but often showed such clear correlations between symptoms and physiological changes, so that a statistical correlation analysis was not always necessary. We found a statistically significant correlation of oxygen deprivation and fatigue in 58% of the studies ($p < 0.05$). A statistically significant correlation evidence for other parameters has been previously demonstrated in primary studies [21,29].

The most commonly used personal particulate matter protective equipment in the COVID-19 pandemic is the N95 mask [23]. Due to its characteristics (better filtering function, but greater airway resistance and more dead space volume than other masks), the N95 mask is able to highlight negative effects of such protective equipment more clearly than others (Figure 3). Therefore, a relatively frequent consideration and evaluation of N95 masks within the studies found (30 of the 44 quantitatively evaluated studies, 68%) is even advantageous within the framework of our research question. Nevertheless, it remains to be noted that the community masks sold on the market are increasingly similar to the protective equipment that has been better investigated in scientific studies, such as surgical masks and N95 masks, since numerous manufacturers and users of community masks are striving to approximate the professional standard (surgical mask, N95/FFP2). Recent

study results on community masks indicate similar effects for respiratory physiology as described for medical masks: in a recent publication, fabric masks (community masks) also provoked a measurable increase in carbon dioxide $PtcCO_2$ in wearers during exertion and came very close to surgical masks in this effect [21].

Most of the studies cited in our paper included only short observation and application periods (mask-wearing durations investigated ranged from 5 min [26] to 12 h [19]. In only one study, a maximum observation period of an estimated 2-month period was chosen [37]. Therefore, the actual negative effects of masks over a longer application period might be more pronounced than presented in our work.

6. Conclusions

On the one hand, the advocacy of an extended mask requirement remains predominantly theoretical and can only be sustained with individual case reports, plausibility arguments based on model calculations and promising in vitro laboratory tests. Moreover, recent studies on SARS-CoV-2 show both a significantly lower infectivity [175] and a significantly lower case mortality than previously assumed, as it could be calculated that the median corrected infection fatality rate (IFR) was 0.10% in locations with a lower than average global COVID-19 population mortality rate [176]. In early October 2020, the WHO also publicly announced that projections show COVID-19 to be fatal for approximately 0.14% of those who become ill—compared to 0.10% for endemic influenza—again a figure far lower than expected [177].

On the other hand, the side effects of masks are clinically relevant.

In our work, we focused exclusively on the undesirable and negative side effects that can be produced by masks. Valid significant evidence of combined mask-related changes were objectified ($p < 0.05$, $n \geq 50\%$), and we found a clustered and common occurrence of the different adverse effects within the respective studies with significantly measured effects (Figure 2). We were able to demonstrate a statistically significant correlation of the observed adverse effect of hypoxia and the symptom of fatigue with $p < 0.05$ in the quantitative evaluation of the primary studies. Our review of the literature shows that both healthy and sick people can experience Mask-Induced Exhaustion Syndrome (MIES), with typical changes and symptoms that are often observed in combination, such as an increase in breathing dead space volume [22,24,58,59], increase in breathing resistance [31,35,60,61], increase in blood carbon dioxide [13,15,17,19,21–30,35], decrease in blood oxygen saturation [18,19,21,23,28–34], increase in heart rate [23,29,30,35], increase in blood pressure [25,35], decrease in cardiopulmonary capacity [31], increase in respiratory rate [15,21,23,34,36], shortness of breath and difficulty breathing [15,17,19,21,23,25,29,31,34,35,60,71,85,101,133], headache [19,27,29,37,66–68,71,83], dizziness [23,29], feeling hot and clammy [17,22,29,31,35,44,71,85,133], decreased ability to concentrate [29], decreased ability to think [36,37], drowsiness [19,29,32,36,37], decrease in empathy perception [99], impaired skin barrier function [37,72,73] with itching [31,35,67,71–73,91–93], acne, skin lesions and irritation [37,72,73], overall perceived fatigue and exhaustion [15,19,21,29,31,32,34,35,69] (Figures 2–4).

Wearing masks does not consistently cause clinical deviations from the norm of physiological parameters, but according to the scientific literature, a long-term pathological consequence with clinical relevance is to be expected owing to a longer-lasting effect with a subliminal impact and significant shift in the pathological direction. For changes that do not exceed normal values, but are persistently recurring, such as an increase in blood carbon dioxide [38,160], an increase in heart rate [55] or an increase in respiratory rate [56,57], which have been documented while wearing a mask [13,15,17,19,21–30,34,35] (Figure 2), a long-term generation of high blood pressure [25,35], arteriosclerosis and coronary heart disease and of neurological diseases is scientifically obvious [38,55–57,160]. This pathogenetic damage principle with a chronic low-dose exposure with long-term effect, which leads to disease or disease-relevant conditions, has already been extensively studied and described in many areas of environmental medicine [38,46–54]. Extended

mask-wearing would have the potential, according to the facts and correlations we have found, to cause a chronic sympathetic stress response induced by blood gas modifications and controlled by brain centers. This in turn induces and triggers immune suppression and metabolic syndrome with cardiovascular and neurological diseases.

We not only found evidence in the reviewed mask literature of potential long-term effects, but also evidence of an increase in direct short-term effects with increased mask-wearing time in terms of cumulative effects for: carbon dioxide retention, drowsiness, headache, feeling of exhaustion, skin irritation (redness, itching) and microbiological contamination (germ colonization) [19,22,37,66,68,69,89,91,92].

Overall, the exact frequency of the described symptom constellation MIES in the mask-using populace remains unclear and cannot be estimated due to insufficient data.

Theoretically, the mask-induced effects of the drop in blood gas oxygen and increase in carbon dioxide extend to the cellular level with induction of the transcription factor HIF (hypoxia-induced factor) and increased inflammatory and cancer-promoting effects [160] and can, thus, also have a negative influence on pre-existing clinical pictures.

In any case, the MIES potentially triggered by masks (Figures 3 and 4) contrasts with the WHO definition of health: "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." [178].

All the scientific facts found in our work expand the knowledge base for a differentiated view of the mask debate. This gain can be relevant for decision makers who have to deal with the issue of mandatory mask use during the pandemic under constant review of proportionality as well as for physicians who can advise their patients more appropriately on this basis. For certain diseases, taking into account the literature found in this study, it is also necessary for the attending physician to weigh up the benefits and risks with regard to a mask obligation. With an overall strictly scientific consideration, a recommendation for mask exemption can become justifiable within the framework of a medical appraisal (Figure 5).

Increased risk of adverse effects when using masks:

Internal diseases
COPD
Sleep Apnea Syndrome
advanced renal Failure
Obesity
Cardiopulmonary Dysfunction
Asthma

Psychiatric illness
Claustrophobia
Panic Disorder
Personality Disorders
Dementia
Schizophrenia
helpless Patients
fixed and sedated Patients

Neurological Diseases
Migraines and Headache Sufferers
Patients with intracranial Masses
Epilepsy

Pediatric Diseases
Asthma
Respiratory diseases
Cardiopulmonary Diseases
Neuromuscular Diseases
Epilepsy

ENT Diseases
Vocal Cord Disorders
Rhinitis and obstructive Diseases

Dermatological Diseases
Acne
Atopic

Occupational Health Restrictions
moderate / heavy physical Work

Gynecological restrictions
Pregnant Women

Figure 5. Diseases/predispositions with significant risks, according to the literature found, when using masks. Indications for weighing up medical mask exemption certificates.

In addition to protecting the health of their patients, doctors should also base their actions on the guiding principle of the 1948 Geneva Declaration, as revised in 2017. According to this, every doctor vows to put the health and dignity of his patient first and, even under threat, not to use his medical knowledge to violate human rights and civil liberties [9]. Within the framework of these findings, we, therefore, propagate an explicitly medically judicious, legally compliant action in consideration of scientific factual reality [2,4,5,16,130,132,143,175–177] against a predominantly assumption-led claim to a general effectiveness of masks, always taking into account possible unwanted individual ef-

fects for the patient and mask wearer concerned, entirely in accordance with the principles of evidence-based medicine and the ethical guidelines of a physician.

The results of the present literature review could help to include mask-wearing in the differential diagnostic pathophysiological cause consideration of every physician when corresponding symptoms are present (MIES, Figure 4). In this way, the physician can draw on an initial complaints catalogue that may be associated with mask-wearing (Figure 2) and also exclude certain diseases from the general mask requirement (Figure 5).

For scientists, the prospect of continued mask use in everyday life suggests areas for further research. In our view, further research is particularly desirable in the gynecological (fetal and embryonic) and pediatric fields, as children are a vulnerable group that would face the longest and, thus, most profound consequences of a potentially risky mask use. Basic research at the cellular level regarding mask-induced triggering of the transcription factor HIF with potential promotion of immunosuppression and carcinogenicity also appears to be useful under this circumstance. Our scoping review shows the need for a systematic review.

The described mask-related changes in respiratory physiology can have an adverse effect on the wearer's blood gases sub-clinically and in some cases also clinically manifest and, therefore, have a negative effect on the basis of all aerobic life, external and internal respiration, with an influence on a wide variety of organ systems and metabolic processes with physical, psychological and social consequences for the individual human being.

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